ROCKS and MINERALS

Edited and Published by Peter Zodac

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Co-Editors of this 25th Anniversary Number.

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PETER ZODAC and ROCKS AND MINERALS

The purpose of this issue of ROCKS AND MINERALS *is to pay tribute to its editor, Peter Zodac, for twenty-five years of devoted service to the cause of popular mineralogy. The issue was a complete surprise to Mr. Zodac. The editorship was taken suddenly out of his hands, and the responsibility for no part of it is his.*

A Long And Hard Road

Exactly twenty-five years ago, in September, 1926, Peter Zodac brought out the first number of this magazine. He was 32 years old, and had a job in Peekskill as engineering inspector for the Westchester County Park Commission. In his spare time he collected minerals. After he began advertising for sale his large accumulation of specimens in POPULAR MECHANICS and Scout magazines, he received so many requests for information about how and where to collect minerals that a popular mineral magazine seemed the best answer. His primary purpose in starting it was to supply such information and to bring together people of like interest. No popular mineral magazine had existed since the termination of Chamberlain's MINERAL COLLECTOR in 1909. After six years of ROCKS AND MINERALS, he gave up his engineering job in order to devote full time to it. His Rocks and Minerals Association, founded in 1928 to help in uniting collectors all over the country, was an added responsibility.

In 1930 there were only four amateur Mineral Clubs or Societies; the New York, Philadelphia, Newark and Maine. In June, 1930, Zodac published a special Maine number, describing in detail the mechanics of starting a Mineral Club. Soon after this, he was deluged with requests for aid in the formation of such Clubs, especially in the west. In each case he supplied names of local collectors and much advice. In 1931 the Mineralogical Society of Southern California was started; then others sprang up all over like mushrooms. In this way, perhaps most of the present amateur Clubs owe their beginnings to Zodac, yet none of them have given him loyal support or many subscriptions.

The rival mineral magazines also owe much to Zodac. When the MINERALOGIST was founded in Oregon in September 1933, its founder was at the time president of the Rocks and Minerals Association! In June, 1933, Zodac had helped this founder organize the Oregon Agate and Mineral Society, supplying him with the names of collectors of the region. There is no feeling of bitterness about this; on the contrary, Zodac feels that the MINERALOGIST has done much good for popular mineralogy.

The going has been hard. There was a time in the late forties when Zodac had a little money in the bank, but mostly he has been in the red or just about breaking even. He has no assistants, no office, does all the work himself. Many criticize, saying he has not been sufficiently businesslike; few have helped, constructively. Peter Zodac will continue to go his way quietly, despite difficulty, for he prefers making friends, and working with youngsters and beginners, to spending his time putting ROCKS AND MINERALS on a sound commercial basis. He may not be successful in a business way, but he has kept his friends. The words of the first advertiser, replying to a request for aid toward the cost of printing this issue are worth quoting: "Enclosed is my contribution. I wish it could have been a million. Money cannot repay the warm, friendly help extended by Peter Zodac to many such as I. The spirit of his giving has been one of the truly fine threads woven in the fabric of a fine family of folks — those of minerals, rocks and earth."

Contributions To The Science

There has been very little recognition of Peter Zodac's service to the science of mineralogy. Yet this service has been great. From the impetus he supplied to countless beginners, has come a popular movement which has played a vital part in the forward progress of American mineralogy. Because that part is indirect, it gets overlooked.

This issue is an attempt by some of those who do recognize Mr. Zodac's contributions to mineralogy to show him that his efforts have not been in vain. A number of the leading professional and amateur mineralogists were asked to contribute articles to an issue honoring Peter Zodac. These articles largely combine popular interest and scientific substance; as such, they stand as the fulfillment of the dual purpose to which ROCKS AND MINERALS was dedicated. For in his first editorial twenty-five years ago Mr. Zodac said, "The purpose of this magazine is to give, in a non-technical way, enough information to interest a beginner in the collecting of minerals, and to instill in him a desire to know more about them." The dual purpose then, is to promote popular and also educational mineralogy.

Mr. Zodac has always wished to aim his sights toward a higher educational level. But so much of his financial support has come from beginners rather than from more advanced collectors, that he has been duty bound to keep the magazine on the beginner's level. This does not overlook for a moment the excellence of those articles written for the magazine by a few such loyal supporters as Ronald L. Ives. The material in this anniversary issue represents the higher educational level, and if readers find it of interest they are asked to communicate either with Mr. Zodac or the co-editors.

In the old days of mineral collecting (see the articles by Palache and Toothaker) there was a much closer union of amateur and professional mineralogists. This was of great mutual benefit. That it no longer exists, is to be deprecated. Scientific mineralogy has gone its way of specialization, and amateur mineralogy has gone so far in the opposite direction that the majority of collectors seem to follow it purely as a hobby, forgetting the science that is its foundation. Both tendencies are regrettable, and a meeting closer to the center is vitally needed.

ROCKS AND MINERALS subscribers can sample such a meeting ground of scientific and popular mineralogy by reading the articles which follow. In most of them there is constant concern over the whys and wherefores of mineral occurrences described and sufficient emphasis upon geological environment and mineral paragenesis to supply an undercurrent of scientific inquiry and meaning to the whole. Adequate mineralogical description deals not alone with the minerals collected, but also with their environment and inferred history. Amateurs could make a genuine contribution to the science if they wished, for they are in a position to record countless mineral occurrences at the point of origin; but to make such a contribution would take serious study and an organized cooperative effort. Amateur astronomers contribute to their science by their lens and telescope making and by their organized observational work. Mineralogical amateurs can make a similar contribution to their science, provided they are willing to make the effort and are helped and directed in it by professional mineralogists. The difference between mineral collecting as a pure hobby and as a hobby pervaded by an educational purpose, is the sort of difference existing between ordinary stamp collecting (no offense meant) and amateur observational work on the variable stars.

There is, of course, one further side of mineral collecting, belonging to both hobby and science, yet separate also in a world of its own. This is the aesthetic side of mineralogy, requiring no more than appreciation for the beauty of a natural mineral in its crystallized form — yet the quality of that appreciation can attain to an art, as in the article SERMONS IN STONES.

ROCKS AND MINERALS still goes on, after twenty-five years, and the original primary purpose of its editor remains no less strong. Even though the educational part of that purpose has not yet been fulfilled, the other part of it, the spreading of human interest, has been nobly done. No one can dispute the accomplishment, and, in closing, we salute both it and its creator as we wish him "Good Luck for the future!"

Arthur Montgomery

PETER ZODAC

SERMONS IN STONES

HENRY SEIDEL CANBY

Reprinted with kind permission of the author from THE SATURDAY REVIEW OF LITERATURE, *Oct. 8, 1932.*

This appeared as an unsigned editorial. When Dr. Canby, distinguished literary critic and editor of The Saturday Review, was asked about its authorship, he admitted writing it himself. His interest in minerals has always been great; here he has put into words an approach to the subject which all collectors instinctively feel.

Goethe, to the best of our belief, was the only man of letters who knew anything about minerals, and his interest was not nice and particular, but rather an outflowing of his passion for any natural phenomenon which, in the heroic age of science, might help along the Great Explanation. While flowers have bloomed through a million volumes, minerals have had very little work in literature, unless the grossly amateur rubies, emeralds, and diamonds of the detective stories count, as they should not.

It may have been the rarity of fine minerals that has kept them out of imagination, but a shrewder explanation would be the extraordinary unobservance of writers. Keen to detect the slightest human idiosyncrasies, and often sensitive to landscape, they do not (except for the English poets) know one bird from another, generalize in flowers, and see all stones as stone. An ingenious Creator could assemble a satisfactory environment for most of them, especially New Yorkers and Chicagoans, from steel, brick, concrete, excelsior, green paint, artificial flowers, as easily as a stage set. This is one reason why the good average writer fits so comfortably into the foothill section of California, where the elements of the landscape all come by mass production, and a simple (though admittedly impressive) assortment of trees, sky, grass, and rocks, does all the work.

Minerals are different. Their infinite variety is revealed in museums, which conceal, however, their value as symbols, by specializing in innumerable "rare earths" which look like common ones, and in obvious gems or show pieces. There is, for example, the tourmaline (which has had one bad novel written about it.) The tourmaline, in its finest specimens, is a perfect symbol of the modern mind. A shaft of striated light, nervous with electricity, grass green at one end, fading to white in the middle, then throbbing to rose, the delicate crystal will conclude in one set of planes at its hither termination and in quite a different set at the other. It obeys laws of chemistry and mathematics so subtle and so seeming contradictory that unity is achieved only through opposition.

Your garnet is even more interesting. Let it mix with mica and quartz, and it will make rocks good for nothing but to grind into abrasives. Give it a soft muddy shale to form in and it will exhaust its energy upon sheer form in intricate combinations of dodecahedrons and trapezohedrons, but lose all color and inner beauty in the effort. Or subject it to the slightest chemical influences from without and, with the tiniest trace of alien element, it will color into cinnamon, rose, emerald green, golden, violet. But let it be crushed in metamorphic rocks until every semblance of crystal is lost and the essential garnet is restricted to transparent color, and one gets those shapeless, pitted nodules of pyrope which cut into gems of a richness that makes the ruby seem cheap.

And there is cyanite. Blue minerals, like pure poetry, are rare, and particularly of that heavenly blue which flowers attain to, but painters find so hard to imitate. The turquoise has it, but with an underglint of green that time betrays. The lapis lazuli is a composite. Azurite is too dark, sapphire also, and the light sapphires are watery. But cyanite is sky blue. Its long, thin crystals sheaf through the matrix, with only length for form, but in a broken rock lie like feathers from a phoenix's wing. It will not make

gems, it is scarcely a crystal, it is of no utility, but, like a lyric poem, simply is.

For similitudes with the activities of the mind, quartz is the least appreciated of all the mineral analogies. Like a clever journalist making literature, quartz can be false topaz or false diamond. It can adapt to and absorb from its environment, becoming amethyst, agate, chalcedony, onyx, carnelian, jasper, rose quartz, or prase that bubbles over the rock like water over moss. It can make grindstones or flints; or it can take up a ten per cent of water of crystallization and become opal flashing every color; yet not firmly held, for heat it above 100° centigrade and off go water and color both. Yet when an old civilization, like the Chinese, with a deep appreciation of the quality of essentials, carves the pure transparency of quartz itself into globes of quivering light, then one forgets the pseudomorphs and curiosities, the self-conscious agates, the pretentious amethysts, and the ornate chalcedonies.

We have scarcely opened the book of mineralogy. There is the diaspore,so rare and so ugly; the calcite crystal, as limpid as the diamond, until a pin scratches it; the beryl that one tiniest trace of borrowed matter turns into emerald, more valuable than diamond. There are the pseudomorphs which are interesting only because they preserve the form of some earlier mineral that has been eaten away. There is rutile, which by itself moulds into rough, ugly lumps, but shoots in exquisite needles through the sustaining fabric of transparent quartz. There are the mock crosses of staurolite, the flat facility of mica, the radiant whirls of tremolite and natrolite, where stone becomes fabric, the admirable texture of many-colored jade. But the wiser Chinese long since recognized in jade reflections of the qualities of life and have given to it poems and whole books.

RECOLLECTIONS OF THREE PHILADELPHIA MINERALOGISTS

CHARLES PALACHE

Professor emeritus of mineralogy, Harvard University; generally considered to be dean of American mineralogists.

The last quarter of the 19th century was marked in the United States by a great revival of interest in mineral collecting. This was doubtless due largely to the opening of new mining districts in the West, after the warring tribes of Indians had been confined to reservations so that prospecting became relatively safe. Dealers new and old in the East were offering glorious new suites of minerals such as Joplin calcites; Arizona and New Mexico wulfenites and vanadinites; Copper Queen malachites; Tintic arsenates of copper; borates from California; and new rich finds in the Appalachian region, in Mexico and Canada. For the first time American minerals could worthily take their place in collector's shelves alongside the well-known old-world specimens.

Philadelphia and its neighborhood was at first the most active center of this new collecting activity and there came into being a number of remarkable mineral collections, foremost of which was that of Clarence S. Bement. Bement had acquired a moderate fortune in the manufacture of machine tools as a partner in the firm of Miles and Bement. He was apparently one of those men whose hobby was *collecting;* he had made and dispersed collections of prints; of Americana; and of early American coins before he turned to minerals. By 1883 he was at the height of his activity; Hoseus, a Swiss dealer, kept a jealous eye on his behalf on new European discoveries; and he had first chance at selection from the finds of Niven, Hidden, English, Foote and other American collectors and dealers. The collection came to number upwards of ten thousand specimens, housed in fine mahogany cabinets filling his office and the second-floor halls of his residence.

To say of a mineral specimen that it was of "Bement quality" was in those days to give it the highest praise that could be phrased. He welcomed study of his suites by scientific mineralogists. E. S. Dana monographed his copper crystals; Penfield his Magnet Cove brookites; von Rath his quartz crystals from North Carolina. Some vague idea of the range and richness of the collection may be obtained from the description of it after it was installed in the American Museum of Natural History by L. P. Gratacap, then Curator of the collection, in the last section of his book, A POPULAR MINERALOGY, N. Y., 1912. There, too, many of the finest wall specimens are reproduced by photography.

My personal acquaintance with Mr. Bement began in the summer of 1898 when I had been at Harvard less than a year. I had begun to study Lake Superior calcites and, having written to Bement at the suggestion of Dr. Wolff to ask for the loan of any he might have, had been invited to come and choose them myself. I happen to have in my file a letter I wrote to my father at the time which tells, I think, quite vividly my impression of the man and his minerals. I quote it in full despite its youthful enthusiasm.

"All day today I have been feasting my eyes (the only adequate expression) on minerals such as I scarcely dreamed existed. Clarence Bement is a man of large means and catholic tastes, most of whose spare time and money have been for many years devoted to getting together, by means of personal travel and agents all over the world, minerals and crystals, the finest that could be found. In a back room in his unpretending house in Spring Garden street stand the cabinets which enclose the finest collection (private that is) certainly in America and of its size doubtless in the world. I went there at 9:30 and from that hour till one and, after a delicious luncheon, again until 6:30 I was taking from the drawers and hand-

ling the wonderful specimens which he had gathered from the ends of the earth. Such form, such color, such splendid groups! And a story to tell of most of them. Here was a glorious emerald crystal in its veinstone, given by a Russian czar to Taglioni the famous danseuse, sold by her in Paris and then into the hands of Bement's agent. Here are matchless quartz crystals picked up by him in in the houses of Alpine 'strahlers' who had found them in the caverns of the mountains. Impossible to tell of all. Here drawer upon drawer of calcite from Mexico — from England — from Lake Superior — from Missouri surpassing in daring and dainty combinations of color, of curious form and grouping the most sanguine imagination of the mineralogist. I am not altogether given to using superlatives but really I have had little else on my lips all day for here is really the best —the *superfine*. Mr. Bement is a delightful host and full of pleasant anecdotes of all the famous collectors and mineralogists of the century, most of whom he has known personally. I finally departed carrying with me the calcite crystals I wanted to study which were the excuse for my visit. He also gave me a beautiful North Carolina quartz crystal as a memento of my first sight of this more than wonderful cabinet."

The next day I met Mr. G. W. Fiss, a friend of Bement, and saw for the first time his micromounts of minerals. These meetings were the first of many and the beginnings of friendships with both these gentlemen that only ended when they passed away. Mr. Bement, when I met him, was already under treatment for cataract and his vision grew steadily weaker from year to year. This was the chief reason why he desired to dispose of his collection; another was that it had grown so large that it crowded the house and was difficult to care for and to show. Dr. Wolff and I had correspondence with him concerning its possible aquisition for Harvard but its value was far beyond possible consideration by the University. It was bought by Mr. Morgan, through George F. Kunz, and given to the American Museum of Natural History. Its high average quality may be judged by the fact that it was displayed as a whole, whatever the Museum had previously had on exhibition in its systematic collection being removed and later sold. That was in 1900, I believe.

I next saw Mr. Bement in his home in 1904. He had then gone into the collection of micromounts with the help of Mr. Fiss who did all the mounting. He exulted in having his whole collection within reach of his chair . . . no running about from room to room. He was perhaps spending as much for specimens to break down so as to yield micromounts as he had previously for his drawer specimens. I was able to supply the two friends with many "scraps" new to their collections and the file, of Mr. Fiss' letters especially, from 1904 to 1924 is a continuous record of our mineralogical friendship. In visits that were all too few I grew to learn something of what Bement called his "Sunday School" — the weekly meetings with him of Fiss, Hancock and later Keeley—together with any visiting mineralogist who was fortunate enough to be at hand. I have always regretted that no one who was a part of that charmed circle made an adequate record of it. Mr. Bement came more and more during his last years of collecting to depend upon Lazard Cahn for his supply of specimens and Cahn became both a valued member of their circle and a devotee of the micromount on his own account. This phase of Bement's collecting activity came to an end in 1912 when his eyesight failed entirely. His large cabinet of mounts was sold to Mr. Fiss who took from it a few specimens lacking in his own sets. He in turn sold it to Mr. A. F. Holden, at whose death shortly afterwards it came to Harvard University.

Mr. George W. Fiss was a noble looking man, tall with a full snowy white beard, splendid carriage and a most charming voice and smile. He was, I believe, a cotton manufacturer but his business never came to the fore in our meetings. On my rare visits to Philadelphia he would promptly give me a huge

and very strong cigar and plant me at his rotating table with the tall Zentmeyer binocular microscope upon it. He always had new mounts and problems of identification. Hours would pass and between the fumes of nicotine, the smell of the paraffine lamp which he always used and eyestrain I would find myself physically exhausted until I could not tell quartz from galena at the evening's end. But I found an unending fascination in his careful preparations. I believe he much advanced the art of making these mounts. He was a dear friend, modest—kind—humble. He passed away in 1925 and his collection was left to his friend F. J. Keeley, Curator of minerals in the Philadelphia Academy of Sciences.

Mr. Elwood P. Hancock, the third member of the triad, lived in Burlington, New Jersey. He died at the age of 82 in 1916 and is said to have collected minerals more or less since he was nineteen years old. He was a landscape artist by profession but also successfully carved wood. When I knew him he was inactive and lived for his minerals alone. I first met him at the home of Mr. Fiss in 1904. From what I heard of his collection I made sure that it must contain many things of particular interest from Franklin. So when I began gathering data from collections in 1905 for my Franklin monograph I arranged to spend a couple of days at Burlington with Mr. Hancock. He was very hospitable and not only did I find there much Franklin material of importance; but I became convinced that his collection, small as it was, had an impressively high average quality.

Acting on a suggestion by me, Mr. Holden wrote to Mr. Bement offering to buy Hancock's minerals for Harvard whenever they became available, at a valuation to be placed upon them by Bement. When Hancock died eleven years later, although Holden was no longer living, his executors carried out Holden's wish and the collection came to Harvard. It still stands in my office in the Museum, a treasured memorial to the two friends. For it is contained in the two handsome cases Bement gave Hancock when the former's collection was sold. Hancock confined his collection to these cases holding about 1500 specimens. If he got something new or better, place was made for it by taking out a poorer piece and thus the average quality had steadily improved. We have kept it practically intact to this day and in his own quite original classification; two things not done with any other of the very many collections the Museum has acquired.

Burlington was not so far from Philadelphia that Hancock could not be a fairly regular attendant at the Sunday meetings all through the winter months. Bement would sometimes throw out of his drawers a specimen which he thought inferior; often Hancock would carry away such a reject, work on it with his endless patience and skill, and perhaps make a thing of beauty out of it by developing a hidden crystal. Then he would bring it back in quiet triumph to the next "Sunday School" meeting and laugh over it with his friend. His means were not large and he rarely bought from dealers. He had made friends among the miners at Franklin and at Tilly Foster who saved their best finds for Hancock's semi-annual visits; nor would they part with such reserved specimens for any tempting price till "John," as Bement always called him, had had a show at them. Mr. Canfield told me this ruefully in recalling some much-wanted Franklin specimen that he had failed to secure.

Hancock collected at Franklin jointly with Mr. Losey of that place and they shared many a find. When I tried to see the Losey minerals in Franklin he was no longer living and his widow was unwilling to unlock the cases. But at my request Hancock came up to Franklin and could tell me the history and exact source of every piece. Holden later bought the Losey collection, chiefly for the suites of corundum and zincite. When examined closely, those specimens which had been worked out of limestone such as franklinite, rhodonite, pyrite and tourmaline by Losey were crude and badly scarred in sharp contrast to the beautiful work of Hancock's hand and tools. In this work

his artistic eye and training was brought to bear and endless patience and incredible skill wrought miracles. In his cases there are long series of the Franklin species just mentioned; still more remarkable are the suites from Tilly Foster. There is a tray each of chondrodite and magnetite; of clinochlore; and various pseudomorphs worked out of the soft massive serpentine or from limestone. Many of them hardly show a tool mark and it is difficult to believe that they have been labored over for days to reveal the hidden crystals.

It was from Hancock that Penfield received the original specimens of the four new species he described from Franklin; hancockite, clinohedrite, leucophoenicite and glaucochroite, all found on the dump of the old Parker Shaft. The type clinohedrite is still in the Harvard collection as are the finest specimens of the rare Franklin species allactite and friedelite which Hancock had preserved but had not identified.

Hancock's minerals in the cases given him by Bement; Bement's case of micromounts each meticulously mounted and labelled by Fiss; and photographs of the three devoted friends stand in close proximity in the room my successors in the Harvard Museum are so good as to still call my office. They keep green the memory of many happy meetings long gone by.

Cambridge, April, 1951.

THE DAYS OF A. E. FOOTE

CHARLES R. TOOTHAKER

Curator, Philadelphia Commercial Museum; early associate of the Foote Mineral Co.; amateur mineral collector.

Albert E. Foote, M.D., was a professor of chemistry and mineralogy at the University of Michigan before the year 1876. He collected mineral specimens, first of all, for teaching purposes, from the iron and copper mines of Michigan as well as amethysts and other things from the shores of Lake Superior. He gathered not only what he really wanted but he could not leave specimens behind him for fear they would be forever lost and wasted, so he brought back barrels and boxes full of everything that looked like a mineral specimen.

He came to the Centennial Exposition in Philadelphia in 1876 and made a handsome exhibit of splendid minerals. He rented a cheap building on North Forty-Fourth Street just outside the Exposition grounds and stored there a lot of material for which there was no room in his exhibit. Visitors, especially teachers of chemistry and mineralogy, saw his display and wanted to purchase specimens. He took them to his little shop outside the Fair Grounds and soon, to his surprise, he found himself running a business. He traded specimens as well as sold them and so built up a large and varied stock. He never "made money" but he had a nice little business and was able to support his wife and three children. He stayed in Philadelphia and I went to work for him in July 1890. By that time he was known to all the great mineralogical museums of the world and to all the important private collectors. I became acquainted with his customers—Clarence S. Bement, George Vaux, Jr., W. W. Jefferis, Colonel Washington A. Roebling and others. It is embarrassing to a dealer to have such clients—every one of whom wants first choice of the best specimens as they come to the store. It requires diplomacy to handle them. I knew Dr. James Leidy who bought for the William S. Vaux collection of the Academy of Natural Sciences of Philadelphia. Of course, I knew Fiss and Rakestraw, early collectors of micromounts.

We were in close touch with Dr. Koenig and with E. S. Dana. Foote never wrote a description of a new mineral for publication or of a new meteorite because he felt that would be bad business policy. During the years I worked with him, the business had two departments: minerals and second-hand scientific books, mostly medical. I was concerned only with the Mineral Department.

The "old man," as we called him, suffered terribly from tuberculosis. By the end of October or November, he was forced to go to a warmer climate to save his life. He would, somehow, scrape together or borrow a few hundred dollars. We would pack up a small trunk with cheap, showy minerals, mostly specimens that we would sell (if we could) for twenty-five cents each. Such things as peacock coal, quartz crystals, calcite, Elba hematite, Sicily sulphur, etc. He would stop first at Joplin, Missouri, and see people with whom he was already acquainted. He would carry in his pockets half a dozen cheap specimens, carefully wrapped in tissue paper and cotton. He would start a conversation by truthfully telling what the things were and where they came from. When he told a man that he had brought them to give to him and then carefully mention that he had still others at his hotel, which he was willing to exchange, and later offered to buy some fine specimens which the man had, he was well on the way to clean out the neighborhood. He presumed on the fact that he was a medical doctor and he would hunt up a local physician who knew which miners had specimens in their houses. He got their names from the doctor and visited them and by sim-

lar friendly approach, he got everything they had. Of course, he made the acquaintance of mine superintendents and chemists. We could be pretty sure of getting a dozen or twenty boxes from Joplin if Dr. Foote stayed there ten days. Then we sold specimens and had money to send to Dr. Foote, perhaps at Pike's Peak, his next stop. He was physically more comfortable in the region of Pike's Peak until the weather got too cold. Then he went to the Organ Mountains, New Mexico, to the Red Cloud Mine and other places in Arizona and New Mexico, and more and more boxes and barrels came in by freight. He marked which boxes were to be opened first and gave us directions to offer certain specimens to Bement, others to Vaux, and he indicated prices on the finest.

I remember the thrill we had when he brought home from Bisbee the two unique specimens of paramelaconite and footeite. These were sold to Bement for $100, and a description of them was published by G. A. Koenig, a well known mineralogist of Philadelphia. Footeite unfortunately was later found by Penfield to be identical with connellite.

Perhaps at this point I may say that I never knew of anyone with whom we traded specimens nor of any individual from whom we bought material for cash who was dissatisfied. The critics were some customers who claimed that his selling prices were robbery, but they failed to take into consideration the fact that he had to pay travelling expenses, support his family, pay rent and pay his employees.

We were always on the lookout for meteorites. I have no idea how many were sent to us. Many were just queer looking stones of no value. Once in a while we got a good one. I remember a piece of iron that someone was using as a door stop. It looked so good that Foote bought it on suspicion. We had a thin slice cut off one end and I etched it. The Widmanstatten figures came out so beautifully that it was put in with the type and was used in printing our advertising. Our biggest thing in meteorites was the Cañon Diablo iron. The first thing we heard was of a "mine of native iron" which we did not believe. In 1891 Dr. Foote went in a hurry to Arizona. He sent home a chunk of iron weighing possibly fifteen pounds. We sent it to a machine shop to be sliced and when the cut had gone three-quarters through it tore the saws to pieces. So they broke it the rest of the way with a trip hammer. We turned the two pieces and fragments over to Dr. Koenig. He reported finding diamonds in the iron. Then Foote contracted with the ranch owner to take all he and his cowboys could find for a year, and he fixed things so that Ward could get none. During that year we sold Cañon Diablo irons to all the great museums and private collectors in the world and we found a dozen or more pieces showing diamonds.

I cannot tell how many suspected irons we had cut that I etched. I passed favorably on some and condemned others in the light of our knowledge at that time. Probably I was wrong in refusing some of them. If we had a suspected stone, it had to show at least specks of metallic iron and on analysis it had to show nickel-iron. No one would believe in anything else, and we not only could not sell it but dared not offer it.

When the weather in Arizona became too cold for him or when he had acquired and shipped everything he could get, he told his friends that he would be back in a couple of years and went on to Mexico — Guanajuato, Zacatecas, Queretaro and other Mexican localities. I remember that once he wrote us from Zacatecas, telling that he had been thrown from his burro into a bed of cactus and how he was still picking out the splinters from various parts of his anatomy. He travelled very cheaply, getting everything he could as gifts or in trade and buying for as low prices as possible, but he wanted to leave a good impression behind him so that he would be welcomed in a friendly way two or three years later.

We had a correspondent who shipped us colemanite from Death Valley, receiving satisfactory payment—part cash, part

trade—and we got all of the best that was found.

He made connection with a professor in the Mormon University, Salt Lake City, and got all of the best of the enormous gypsum crystals and lots of the Thomas Mountain topaz when it was new. We got almost all of these things in exchange. If anyone dreams that we did not pay well, just go to the University in Salt Lake City and see what we gave them. The professor, Dr. James E. Talmage, later one of the twelve Apostles of the Mormon Church, was my own dear friend until his death.

All of our exchanges and purchases were aimed at two things: first, to get at the lowest possible price the finest cabinet specimens obtainable and a good stock of cheap specimens; secondly, to be sure to make friends of the people who were our sources of supply and to treat them fairly and insure their good will for future dealings. Both these things we did successfully.

In alternate years Dr. Foote would go to Europe. We started off by picking out a lot of really top-quality specimens, which we selected very carefully and shipped to the British Museum on approval. These things would go perhaps in May or June. The shipment contained, first of all, half a dozen specimens we felt sure the British Museum would buy. Then we added perhaps a dozen or twenty which we thought they would not purchase. That saved us the ocean freight on some good stuff that could be sold to other European museums or private collectors. We packed a few boxes of fine specimens and shipped them to an address in Paris where Dr. Foote could pick them up in November. He went first to London about November 1 and got the things the British Museum did not want. He either took or sent them to Paris where he would not stay at an expensive hotel. European collectors came to see him as did the buyers for the Vienna and other museums. When he sold out what he had, it gave him money for the winter and to come home.

Twice he visited Sicily and I think no one else ever brought away such a quantity of both magnificent and common specimens. There were the most wonderful specimens I have ever seen of sulphur, aragonite, calcite after aragonite, selenite, etc., not to speak of rarer things like melanophlogite.

Twice he went to Elba and we had hematites and pyrites—so many and such wonderful specimens as no one else has ever brought to America.

Once he went to Sardinia and obtained magnificent anglesites and phosgenites—plenty of them. On his way back home he met in Paris his friend and business rival, Ward. Each of them carefully told the other where he had been and what he had gathered. Ward wanted to see the specimens from Sardinia. Foote let himself be persuaded to show some of them. Ward saw anglesites and phosgenites such as we later sold for fifty cents. Foote did not lie to Ward but he let him think that these were good. With great seeming reluctance, and as a personal favor, Foote sold some of these to Ward. Six months later, when Ward came to our store and saw what we really had, he called Foote an old scoundrel. Foote laughed and then Ward laughed too.

Another year, he went to the antimony mines near Constantine, Algeria, and then we had senarmontite and valentinite by the hundreds of pounds, some of the senarmontite in big crystals.

One year when he went to Sicily, he stopped in Naples, spent a few days with A. Scacchi, and studied Vesuvian minerals. He bought from Scacchi a fine set of typical specimens. He found a guide on the mountains who had helped Scacchi and bought from the guide (Macaroni) a lot of boxes full of such stuff as the Italian professor had collected. Macaroni had a ton or more which Scacchi did not need. Foote shipped it all home. There were chunks of stuff from Monte Somma twice the size of your head and plenty of small pieces. Foote taught me what he knew, gave me the literature, and it was my job to break up the stuff, identify it, label it and put on the prices. I surely

learned the minerals of Vesuvius, nephelite, sodalite, sanidine, garnet, biotite, hauynite, etc.

Then one year Foote went to Laurium, Greece, and we had adamite and smithsonite from the mines and laurionite and phosgenite in the slag. We had several hundred pounds of the slag and it was interesting to break it up.

On one occasion, a Swedish professor, A. Sjögren, visited the store, stayed several days and bought many fine specimens. Quite soon after, Foote visited Sweden and sent home from Pajsberg wonderful specimens of rhodonite, hematite and a dozen or more other minerals.

In the year 1895, Dr. Foote was appointed on the State Commission to install and furnish a large part of the Pennsylvania exhibit in the Mining Building at the Atlanta Exposition. We got together a handsome display and he and I went to Atlanta to set it up. The weather was rough and cold. He stayed longer than he should have done and died there, leaving me to carry on.

His son did a little collecting both before and after his father's death. His best job was a wonderful lot of big molybdenite crystals from Pontiac County, Quebec, Canada. Sometimes I wonder where all those specimens have gone. There were well-formed, six-sided crystals, four inches in diameter and one and one-half inches thick.

Foote believed in education and so we put up a set of one hundred specimens, thumb-nail size, which sold for $1.00. Another set of one hundred, average size one and one-half inches, sold for $5.00, and a set of specimens each about two by three inches for $10.00. Each set contained native elements, sulphides, sulphates, carbonates, silicates, hydrocarbons, etc. A collector today would feel he was getting a bargain if he paid $3.00 for tetrahedrites from Kapnik, Hungary, such as we put in our collection of one hundred specimens for $10.00.

We sold material by the pound to college laboratories for teaching chemical analysis.

Somewhere about 1893, I think, we sold ten pounds of rutile from Magnet Cove, Arkansas, to a chemical research firm in Pittsburgh. Later orders boosted this to a thousand pounds or more. We never learned what they did with it. This was one of the earliest sales of a "rare" mineral in quantity for commercial purposes, but we knew where there were plenty of deposits of other more or less rare minerals. There was molybdenite, for example, not crystallized, and so not tempting to the dealer in mineral specimens. Memoranda of these things were in our notebooks.

Foote's son (Warren M.) studied at the University of Pennsylvania, and later at the Ecole des Mines in Paris. On the death of his father, he took charge of the business and by force of circumstances found himself selling minerals by the hundred pounds and then in ton and carload lots. The sale of specimens meant less all the time and by the year 1905 he dropped the specimen business entirely because the firm was making money selling "rare" minerals in quantity. It has sometimes shocked me to see at the plant of the Foote Mineral Company big bags of samarskite, for example, dumped into the crusher and to realize that wonderful crystals were being lost to collections simply because it did not pay to employ a man to watch for them and pick them out.

I stayed with the firm until 1897 and saw just the beginning of this change. I know that in the end they threw hundreds of good specimens into barrels which went to the dump.

THE SAPPHIRE MINES OF KASHMIR

RICHARD V. GAINES

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In August, 1944, while stationed with the U. S. Army in India, I was fortunate enough to obtain twenty days' leave, which I used to make a trip to the Kashmir sapphire mines. These mines are in an almost inaccessible part of northeastern Kashmir State, about 150 miles from the nearest road. I had done a considerable amount of planning beforehand, and had secured the best available maps, which were quite good. My companion for the trip was Capt. Robert C. Rice, AAF, who, although not a mineralogist, went along for the adventure and the exercise.

We went by train from Calcutta to Pathankot, in Punjab, via Delhi and Amritsar. This distance was about 1400 miles. From there, by car, to Dalhousie in the foothills was 52 miles. From Dalhousie to the mines, we walked, utilizing coolies and, in the few places where obtainable, baggage ponies to carry our food and equipment. The localities we passed through on the way to and from the mines, with the exception of Chamba and Kishtwar, were little more than collections of huts, and do not show on any but the largest scale maps. I enumerate them, however, as a matter of interest to anyone who might be in a position to duplicate our footsteps: Dalhousie in Punjab to Chamba in Chamba State (1day); up the Siyul Valley to Alwas (3days), over Sach pass (14,328 feet) to Kilar in Pangi (3 days); down the Chenab Valley to Atholi in Kashmir State (2 days); up the Bhut Nala (valley) to Matsel in the Padar District of Kashmir (2 days); up past Soomjam to Kudi, where the mines are, and back to Matsel (2 days); back to Atholi (2 days); down the Chenab valley to Kishtwar (2 days); to Batote on the Jammu-Bhanilal road (3 days); by bus to Jammu (1 day) and thence home by train via Lahore and Delhi. The total elapsed time was 25 days but by taking advantage of a week-end at the beginning of our leave we were only three days late in getting back.

Such a long trip might seem an excessive effort in order to visit the actual locality for less than a day. However, in spite of reasonably good advance information, we underestimated both the distance we would have to walk and the conditions we would encounter. On at least half the days, we made double the distance normally considered a day's travel on the trails. Our total distance from Dalhousie to Batote was 325 miles, which we accomplished in 19 days of actual walking, the maximum distance for any single day being 28 miles. We returned a different way than we went out, because we found out that it would be shorter and easier; however, it was also a less interesting route, and the scenery, while impressive, less grand than in the first half of the trip. In any sense, the trip would have amply repaid our efforts whether or not we had actually reached our goal, and I did not feel cheated in the small amount of collecting I had time to do.

The country we passed through was extremely rugged, in part consisting of snow-capped and glacier-encrusted mountains of the main Himalaya range, over 20,000 feet high, and in part of lesser mountains, precipitous gorges, heavy forests of magnificent timber, and some open stretches above timber line but below the snow, which were solidly carpeted with flowers of every imaginable color. This country is very sparsely settled, with only here and there little collections of stone or wooden huts, where the natives try to farm the precipitous slopes. Provisions of any description were practically unobtainable en route, and we subsisted on K rations, much to the amazement of our coolies. Only occasionally were we able to buy a few eggs, cucumbers, tomatoes, or hot peppers. The coolies would not

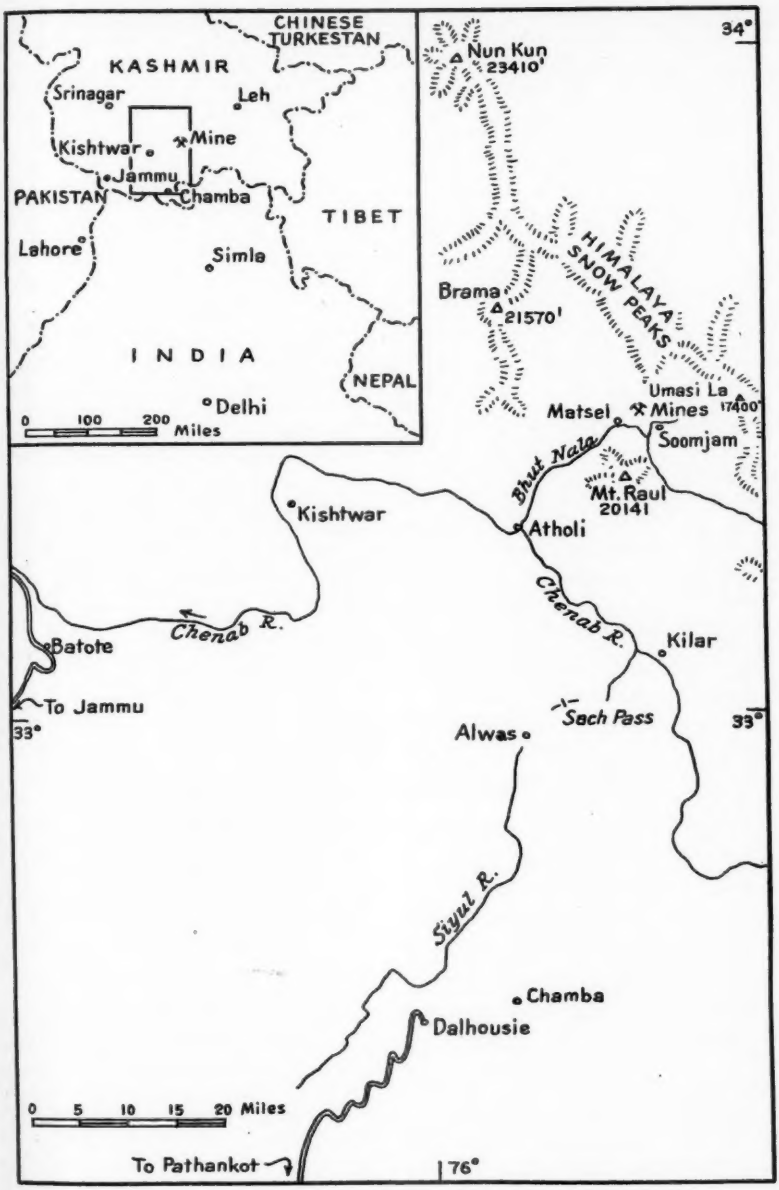

Fig. 1

A portion of India and Kashmir, showing location of the sapphire mines and the routes of approach.

venture to travel beyond a zone with which they were themselves familiar, and so generally a new set had to be hired at each overnight stop. We stayed where possible at government rest houses, which are cabins maintained for forestry officials, tax-collectors, or other state functionaries who have occasion to be travelling through the region. British people traverse that region only rarely, for hunting or trekking, and it is entirely possible that we were the first Americans to cover much of our route.

The climate for the most part was dry and sunny, like autumn weather in the temperate zones. Many of the valleys and snowcapped mountains were immense, and inexpressibly beautiful, in particular the region around Pangi, and up the Bhut Nala, which was carpeted with forests of holly and of English walnut. The valleys were filled with roaring torrents, which rose every afternoon as the warmth of the sun was felt on the glaciers, and receded again before morning. It is doubtful if at any part of the trip we were out of earshot of rushing water, and even today, I cannot listen to the noise of rapids without thinking of this trip.

Access to the mines is normally obtained only through H. H. the Maharajah of Kashmir, whose monopoly the mines are. He maintains a large staff of Kashmire police strategically located in posts at the mines and covering every conceivable approach to them from miles away. These police are under strict orders to allow no unauthorized persons to approach the mine area. Although I did not have the required permit, I had, nevertheless, some documents with me from the Geological Survey of India. With these and with the help of my uniform, I was able to convince the inspector of police at Matsel, the main post, after considerable difficulty that my visit was official, and he allowed me to proceed to the mines and inspect them. However, we could do this only in the company and under the surveillance of one or more of the Maharajah's constabulary.

These negotiations took several hours of our precious time. That afternoon we were permitted to proceed in the company of a police official, and we went several miles further, climbing slowly along a stream bank to Soomjam. Here the broad valley we had been following curved toward the east, toward a pass known as Umasi La, which was little more than a narrow cleft in the rock at an elevation of 17,400 feet. Through this pass funneled all of the traffic between this part of Kashmir and Leh in Ladakh which is close to Tibet and the border of Chinese Turkestan.

Soomjam is the location given in most references as the source of the sapphires. It is the nearest permanent settlement to them, but the mines themselves are six miles further on and at an elevation of 4,500 feet higher. Soomjam lies on the slope of a huge scrubby moraine, and consists of a large fort-like building of stone and wood which houses a police post commanding the approaches to the mine from the direction of Umasi La, and is also the home of a number of sheep herders. We did not stop there, but continued on and upward, a climb of 3,000 feet in three miles up a steep grassy talus slope to Kudi. Kudi is a single barracks-like building situated at the lower edge of a small hanging valley along the rim of which the sapphires are found. It is actually an elongated cirque, carpeted with grass and strewn with large blocks of talus that have fallen from the jagged ridges surrounding it. The single building is inhabited only during the summer months when the valley is free from snow. Then it serves as the headquarters of a detachment of police guarding the mines.

All of this security seemed a little silly, as the mines were not being worked that year and as the operations during the last few years that they did work were reported to have been unprofitable. Although the quantity of sapphires recovered from the underground workings was large, the quality in recent times was mostly very poor, and the stones were badly flawed, pale, and spotty. However, the possibility was always there that if large numbers of persons were permitted

access to the area, some fine large gems might be discovered and stolen such as were found in the earlier alluvial workings sixty or more years ago.

After a cold and uncomfortable night spent at Kudi, we were allowed to proceed to the mining area, which lies on both sides and along the crest of a sharp ridge at about 15,000 feet. Here, also was another police post, a small, square two-story wooden building perched on the very top of the ridge. A sergeant of police and two constables constituted the garrison of this post, and I gathered that the name, Black House, was given it because of the cold, bleak, and altogether rugged and precarious existence led by those who stayed there. A small platform near the house, built to overhang the edge of the cliff, overlooked the acre or so of mine workings, and a guard with a rifle was on constant duty on this platform.

The geological setting of the mine is inadequately known; although it has been described by La Touche (1), and Middlemiss (2), and a geologic map of the mine area has been prepared, only a rough concept of the geologic conditions can be derived therefrom.

In general, the area is one of gneisses and felsic igneous rocks of unknown age. At the sapphire locality there is a banded series of strongly metamorphosed sediments consisting of successive layers of biotite gneiss, garnet gneiss, hornblende gneiss, and marble. The biotite gneiss, which is the most abundant rock, always contains some graphite, and in places graphite constitutes 35% of the rock.

These beds are steeply dipping and are intruded by numerous small, discontinuous pegmatite dikes. In places in the thickest marble member, the marble has been altered to a tremolite-actinolite rock over considerable areas. This rock is a bright green color when fresh and locally contains small amounts of opaque corundum. Where the actinolite rock is penetrated by pegmatite veins, the pegmatites themselves contain some corundum. It was in altered portions of some of these pegmatites that all of the best sapphires were found. Here the feldspar was altered and contained large lens-like bodies of soft kaolin. The kaolin, which had the consistency of potters clay, could be easily extracted and here sapphire crystals ranging up to three inches long were found in great profusion. According to accounts, mining the sapphire lumps in the clay was "like digging potatoes," and the sapphires occurred as thickly as "plums in a pudding".

During the two or three years right after the deposit was discovered, before the then ruler of Kashmir realized what a treasure he had in his territory and clamped strict control on the mining activities, large quantities of the sapphires were recovered in place and in alluvial workings immediately below the mine area, and these were brought by traders to Simla and other places in the foothills and sold for ridiculously low prices — according to reports for as little as one rupee a seer (about 15¢ per pound). Many of these early found stones were quite large; La Touche mentions seeing several in the State Treasury in Jammu in 1887 which were five inches long by three inches across and of good color.

The mineralogy of the sapphire deposits is, as far as could be determined, quite simple, although unusual. The sapphires themselves as mined have the appearance of irregular finger-like lumps about 1" to 3" long, having somewhat pointed ends. They are actually barrel— or spindle-shaped rhombohedral crystals of corundum, all coated with a tenaceous covering of kaolin, and almost invariably more or less pitted and corroded. The kaolin gives them the appearance of having been dipped in whitewash and allowed to dry, but in many cases this can be scraped or flaked off if the surface underneath is not too deeply pitted.

Beneath this surface coating the underlying corundum sapphire shows up as milky gray, bluish gray, or blue-black colors. This crude sapphire material is known locally as "nilam" and of every hundred crystals only three or four will contain any clear areas sufficiently large to constitute gem material. The color of the gems varies from colorless through pale and sky blue

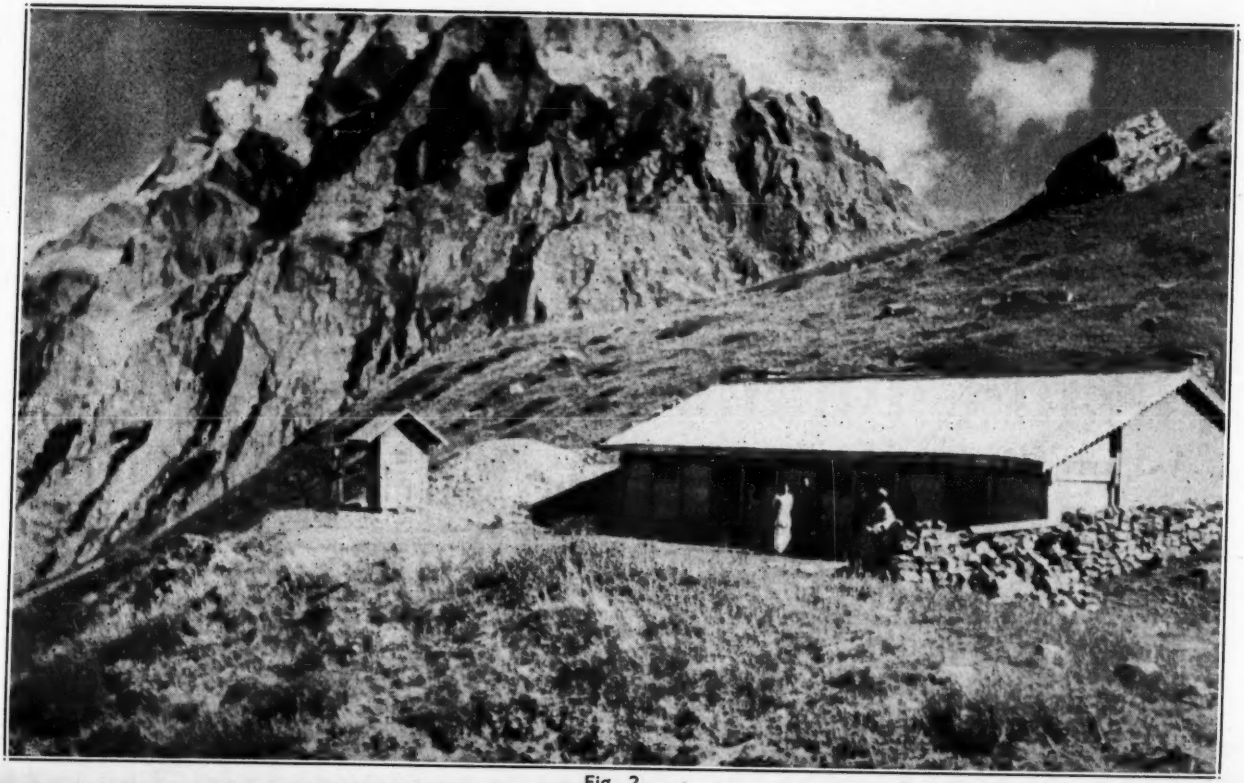

Fig. 2
Police post and sentry box at Kudi (13,500 ft.). Mt. Raul (20,141 ft.) in background. View is south.

to deeper shades and finally blue-black. The most desired color is a rich, bright blue often called "electric blue", and this color was so characteristic of the stones recovered in the early days that now jewelers use the term "Kashmir sapphire" to describe any stone from whatever source that has this color. It is the most costly type of sapphire in the gem trade.

Other minerals observed on the dumps outside the adits were black and dark green tourmaline in good crystals, microcline in small crystals perched on the tourmaline; andalusite, kyanite, quartz, and bright green bladed actinolite. The actinolite areas in the marble are probably caused by contact metamorphism either related to the intrusion of the swarm of small pegmatites in the mine area or of an underlying granitic stock.

One large block of material which formed part of an outcrop at the mine consisted of a greyish white translucent mineral similar to vein quartz in appearance, thickly dotted with crystals of opaque bluish gray corundum about 1" to 2" long, and also containing abundant kyanite and andalusite. A specimen of this material I collected for study was later lost and so I was never able to identify the massive mineral which formed the matrix. At the time it seemed to me to be milky quartz; however, upon later reflection, the possibility occurred to me of its being massive nepheline, which would be a more likely host for corundum. If so, the deposit has many similarities to the nepheline corundum deposits of Bancroft, Ontario, Canada. Furthermore it was never clear to me why portions of the feldspar in the pegmatite dikes would be completely converted to kaolin and other parts were fresh and unaltered right to the surface. If the kaolinized portions of the dikes represented parts which had been massive nepheline, then the kaolinization could readily be explained on the basis of differential weathering. This phase of the geology of the deposit certainly merits further study.

One of the objectives of my trip was to visit the locality close to the sapphire mines where rubellite had been described and also to look for euclase, which had been described from this locality by La Touche (1). The rubellite locality was reached by continuing up the ridge to where it leveled out somewhat at an elevation near 15,500 feet just before reaching the upper edge of a sheer precipice dropping 500 feet to a small glacier in another cirque below. Much pegmatite float was seen on the way up there, and many of the loose blocks had cavities in them lined with quartz and microcline crystals. Several such specimens showed the broken off stumps of clear pale aquamarine crystals and of almost clear green and pink tourmaline. The largest pocket seen was about eight inches across, and from it a splendid beryl about ¾ inch in diameter had been recovered. Near the summit the source of all this float was found. This proved to be a pegmatite outcrop about 15 feet wide by 100 feet long. Mostly it was barren, and where there were vugs all crystals of value had been removed. There was no time, nor had I the equipment, to try to break into any new pockets even if I could have found them.

No euclase was found here or elsewhere in the area. Much later I had occasion to see La Touche's original material which he had described as euclase in the collections of the Geological Survey of India in Calcutta. It proved to be nothing more than green tourmaline.

After seeing all of the rubellite I had time for, we were permitted to visit the sacred area in which the sapphires occurred. This was at a location called the "new mines" area, directly below the sentry house. At this place, which was on a 40° slope, there were a number of adits and dumps, all in an area of less than an acre. The adits were without exception blocked up with close-fitting walls of stones, and it was impossible to tell what was inside. Some, we were told, were worked out, while others had been just in the process of development when mining ceased the previous year. On the dumps outside these adits we were able to spot numerous small fragments and crystals of bright blue sapphire,

Fig. 2 Police post and sentry box at Kudi (13,500 ft.). Mt. Raul (20,141 ft.) in background. View is south.

Fig. 3

Distant view of mine area looking north from Kudi. "Black House" is at top of ridge in the center of the photograph.

which had been washed free by the year's rains and melting snows. We picked up numbers of these, which were too small to have any value; nevertheless we were obliged to hand them over to the constables, six of whom were watching our every movement like so many hawks. We eventually tired of this tantalizing pastime.

Late in the afternoon we had to start back, and we went from the mine area all the way to Matsel by dark. As it was all downhill, this was not too difficult. I was carrying about thirty pounds of specimens collected at the mine, but had to leave them with the police at Matsel as they would not let them through without official sanction. Upon returning home, I applied for such sanction and eventually received it; months later the specimens were carried out by coolie over the same route we took and shipped to

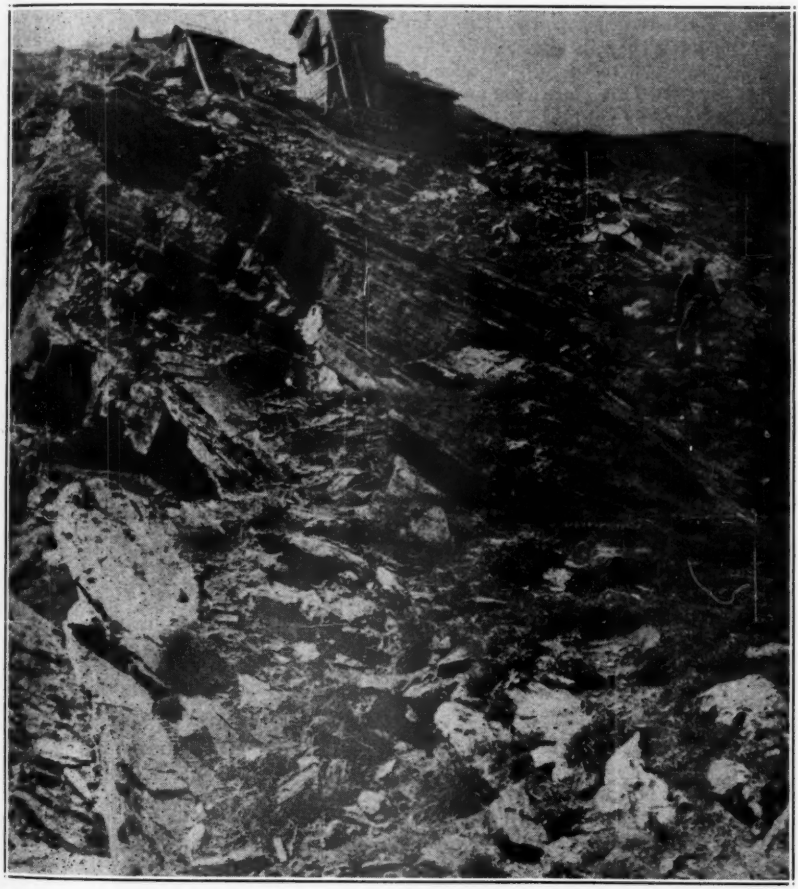

Fig. 4

"Black House"—Police post at the sapphire mines. "New Mines" area is among the outcropping on the left. Elevation about 14,775 ft.

Calcutta, and thence by ship to the United States. About eighteen months after the trip to the mine, by which time I was working in another mine in Colombia, I was notified that the specimens had reached America, only to find out some time later that they had been lost without trace somewhere between the dock and my home! And so, with the exception of a few photographs, I have no tangible evidence of having visited the mines.

The product of the Kashmir sapphire mines all goes to the State Treasury at Jammu, and is sold by that agency at infrequent auctions. Some months prior to my visit there had been such an auction. When we passed through Jammu on the way back to Calcutta, I had a few hours to wait for a train, and after extensive inquiry discovered the name of a merchant who had purchased much of what was sold at the recent auction. He had already disposed of the more valuable gem material, but showed me great bags of "nilam" having little or no value. I did obtain from him one small group of sharp sapphire crystals, and a few rather rough crystals with gemmy portions, and in addition obtained some fine crystals of pale aquamarine, green tourmaline, and rubellite. All of these had been found within ten miles of the sapphire mines, where gem pegmatites are fairly common and have been mined sporadically but never really exploited. Many of them are on the mountain slopes between 12,000 feet and snow line, (which is approximately at 18,000 feet) and are quite inaccessible to anyone except a hardy mountain climber.

I feel that further geological study of the sapphire mines area would probably reveal additional sapphire producing kaolinized pegmatites, for the present workings have penetrated at most a few tens of feet into the mountain side. But it is a rugged location, and free from snow during only three to four months of the year, so that opportunities for studying and exploiting the deposits are decidedly limited. During the summer months the entire region has an unsurpassed climate, and the scenery and opportunities for mountain climbing make it an ideal spot for a trek and a vacation. Opportunities for mineral collecting are also excellent; even if it were impossible to get permission to collect at the sapphire mines, there are known to be many pegmatites of interest in the near vicinity which are quite unrestricted. I hope some day to return there and to be able to enjoy the surroundings at leisure.

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FIBROUS VEIN CALCITE AT LEWISTON CITY QUARRY MAINE

LLOYD W. FISHER

Former professor of geology and mineralogy, Bates College; died, Jan. 30, 1951. It is especially appropriate to have this article, of Prof. Fisher in view of his ever friendly encouragement and support of Rocks and Minerals.

Abstract: Numerous narrow veinlets of fibrous calcite occur in closely spaced vertical fractures and in some cross-fractures of an olivene-bearing basaltic dike in the Lewiston City Quarry. Few references to a truly fibrous calcite are found in the literature. The uniqueness of this occurrence is in the fact that but one of the fifteen dikes exposed in the quarry carries this fracture-filling fibrous calcite.

Location

The abandoned Lewiston City quarry is in the southwestern part of the city of Lewiston, Maine, and was developed chiefly into impure marbles of Androscoggin age cut by Carboniferous pegmatites and Triassic basalts (1). The impure marbles appear to be on the flank of a northeasterly plunging syncline.

The Basic Dikes

There are at least 15 basic dikes exposed in, and near the quarry. Most of the dikes are nearly vertical in their attitude throughout the 55-foot high quarry face. The dikes average about 3 feet in width; the narrowest one is 2 feet four inches and the widest is 14 feet. All of the dikes strike in the same general direction, between N. 51° and N. 63° E. The horizontal distance between successive dikes is from 12 feet to 63 feet.

Mineralogical differences within the dikes allow division into four chemical types:

a) those with visible feldspar phenocrysts
b) those with visible pyroxene phenocrysts
c) those with visible olivene phenocrysts

Contact relationships with the enclosing rock, marble or pegmatite, allow establishment of two categories of basic dikes regardless of their mineral content:

d) those with visible calcite phenocrysts
a) dikes with frozen or chilled contacts with enclosing rock,
b) dikes with loose or greatly weathered contacts.

The calcite-bearing dike is one of the three dikes that fit into the last category.

Petrography of Dike No. 5

Dike No. 5, the calcite-vein bearing dike, is 2 feet, 11 inches in width, has an extremely loose and weathered contact with the enclosing marble, and is the third widest of the 15 dikes exposed. The groundmass is made up of irresolvable fine grained material in which there are subhedral to lath-shaped feldspars, chiefly labradorite; rounded and corroded olivene phenocrysts altered to serpentine and talc and cut by calcite veinlets, in some instances; delicately pink tinted pyroxene altered to serpentine, in part; scattered magnetite grains; and calcite in irregular disseminated crystals or in thin, fibrous veinlets.

The chemical analysis of the dike is given in Table 3, p. 116, Fisher (1)—and shows 8.75% CaO and 5.54% CO_2. If all of the carbon dioxide is united with calcium oxide to form calcite, about 70% of the stated calcium oxide would be accounted for, and the remaining 30% would enter into the feldspar and the pyroxene.

General Characteristics of Dike No. 5

The dike is exposed for 45 feet vertically in the quarry face. The contact with the enclosing marble is greatly weathered. Vertical fracturing of the dike is prominent and this vertical fracturing together with well developed fractures at right angles has allowed weathering to develop the typical "step-like" structure (Fig. 2). Percolating waters have weathered the marble-dike contact and formed a yellowish-brown soft and highly disintegrated

Fig. 1
Face of Lewiston City quarry showing two basaltic dikes.

Fig. 1
Face of Lewiston City quarry showing two basaltic dikes.

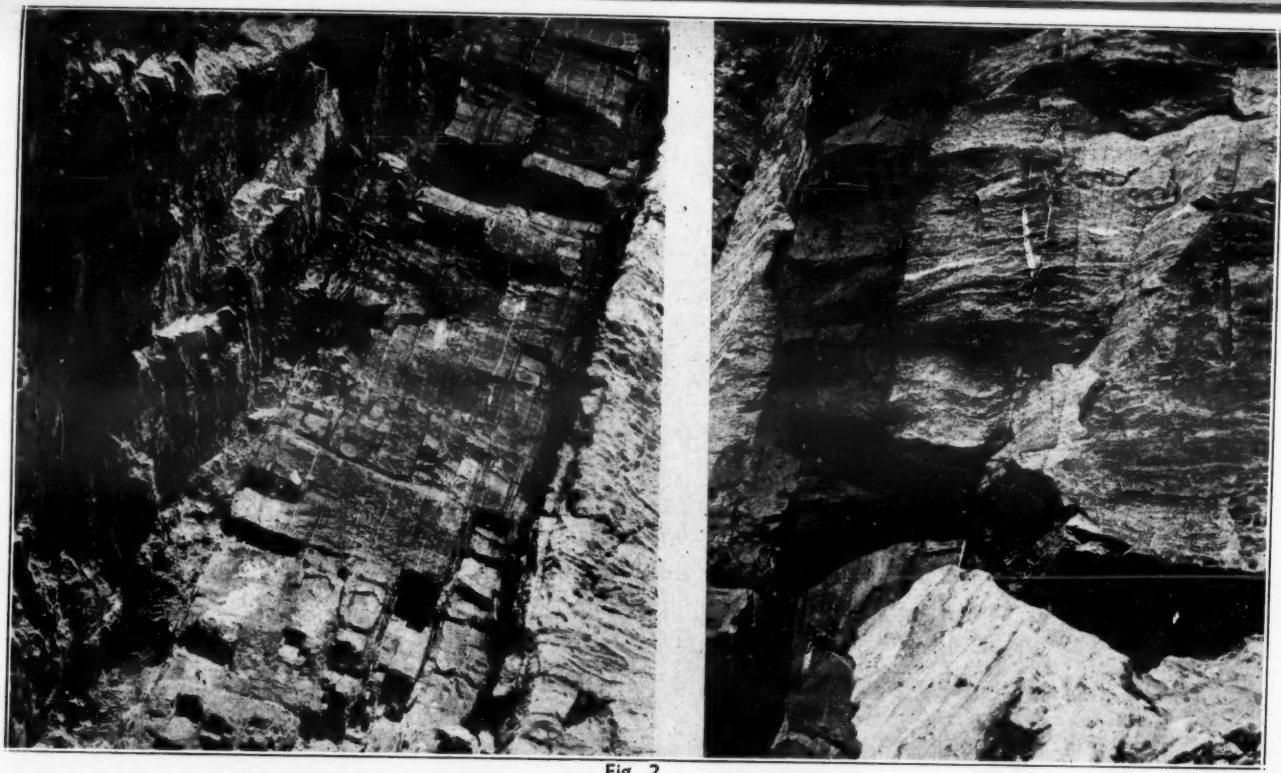

Fig. 2
Left: Dike 5 showing fractures filled with fibrous vein calcite; Right: Dike 6 showing tight, chilled contact.

zone from 3 to 6 inches wide on both sides of the contact. The outer edge of the dike spalls off into irregular fragments that are almost paper thin and are three-four or five-sided. That these fragments have been broken off due to swelling during the process of hydration is indicated by their specific gravity of about 2.675. The yellow-brown altered material is principally an admixture of limonite, quartz, and calcite.

There are numerous more or less uniformly spaced continuous vertical fractures in the dike that are filled with fibrous calcite. Several of the cross-fractures carry calcite (Fig. 2).

Physical and Chemical Nature of the Dike

The specific gravity of fresh dike material was determined from 10 random chips and ranges from 2.766 to 2.845, with an average of 2.881. One of the chips used for gravity determination enclosed a 3 mm. width vein of fibrous calcite. The specific gravity of this chip was determined as 2.776 before the calcite was removed by solution in 1:4 acetic acid. Fourteen percent by weight was dissolved from the dike and the specific gravity recalculated as 2.826. This average specific gravity of 2.811 and the range of specific gravity indicated is well within the limits of the average for basalts as determined from analyses of 42 basalts listed by Washington (Chemical analyses of Igneous Rocks, Professional Paper, 99). These 42 basalts showed an average of 2.788 S. G., with the highest gravity of 2.980 associated with high CaO-basalts.

The chips used for specific gravity determination were crushed and quartered and used to determine average solubility of the dike material in 1: 2 HCl. Solubility ranged from 19% to 24%. Solubility of similar material in 1: 4 HCl averaged 8.3%. These differences in solubility can be explained by the presence or absence of calcite, either as a secondary accessory or as minute vein-filling material.

Heavy mineral determinations (bromoform 2.84) indicate about 45% heavy minerals. Binocular examination of the heavy portion showed magnetite, olivene, pyroxene, and an undetermined greenish-black mineral.

The fibrous calcite

As stated before, all of the vertical fractures in the dike under discussion contain a fibrous form of calcite—argentine. The vertical fractures are closely spaced for the most part, 2.5 to 4 cm. apart. The calcite fibers are formed at right angles or nearly so to the enclosing dike-walls. Some of the calcite filled fractures or veinlets are 0.5 cm. in width. Some of these veinlets are entirely calcite but others show some small fragments of dike material enclosed in the vein. The small fragments of dikes are not generally parallel to the walls of the vein nor at right angles to the calcite fibers. The boundary walls of the veins are moderately straight but here and there slight protuberances of calcite go beyond the main vein into the dike. Some of the larger calcite veins bifurcate and small veinlets follow from the main veinlet across irregular fractures in the dike.

Characteristics of the Calcite

The color of the calcite is white to creamy white to clean gray white. The luster is silky to lustrous. The habit is distinctly fibrous with fibers practically at right angles to the enclosing walls. The color, luster, form, all approach the typical laboratory variety of satin spar gypsum although the latter is slightly more lustrous than the vein calcite. Calcite of the veins was crushed through 100-mesh and caught on 150-mesh for study under the petrographic microscope. Similar comparison specimens were made of aragonite, Iceland spar, scalenohedral calcite and gypsum. In no case does the vein calcite show any breakage or cleavage along lines similar to those developed in Iceland spar or scalenohedral calcite. The forms resulting from the crushing of the fibrous vein calcite resemble rather closely the crushed satin spar.

The index of refraction of the vein calcite for epsilon is 1.485-1.488 and for omega, 1.655-1.660. The vein calcite is

completely soluble, without residue, in 1:4 acetic acid.

The Origin of the Veinlets

Two types of origin for the calcite enclosed in the dike proper may be discussed in relation ta (a) the disseminated calcite and (b) the fibrous vein calcite. It is probably a well established fact that calcite may form during the solidification of magma but most of the primary calcite described in the literature is associated with granitic or syenitic rocks and not with basic dikes. Bowen and others have suggested that carbonates may be introduced in water solutions and replace silicates. Secondary calcite may be formed in igneous rocks from calcium derived from calcic feldspars or by carbonated waters carrying dissolved calcite. Daly (2) regards the calcite dikes of the Premier Diamond Mine, Transvaal, as essentially magmatic though somewhat modified by the invasion of water, gas and CO_2 near the close of the cooling process.

The disseminated calcite: The distribution of the disseminated calcite in thin sections is suggestive of a derivation from the calcic feldspars and perhaps, in part, from the pyroxene.

The fibrous vein calcite: A study of five thin sections cut so that all possible orientations of the veinlets could be studied indicates a secondary origin for the vein calcite. Several minute veinlets traverse the body of the dike and traverse pyroxene altering to serpentine and calcite. In one instance, fibrous calcite parallels a fracture in labradorite.

Summary

After the intrusion of the Triassic basaltic dikes into the impure metamorphosed limestones, the cooling of the dikes brought about a development of minute and somewhat evenly spaced vertical and cross-fractures. These fractures later served as channels for the downward percolating ground waters which traversed the enclosing marble. Scattered inclusions of pegmatite in the upper surface of the quarry and striated and polished top surfaces of basaltic dikes indicate a large amount of marble removed from the area. After the percolating waters carrying calcium bicarbonate had filled the minute dike fractures, air was excluded and crystallization of the calcite in its fibrous form occurred.

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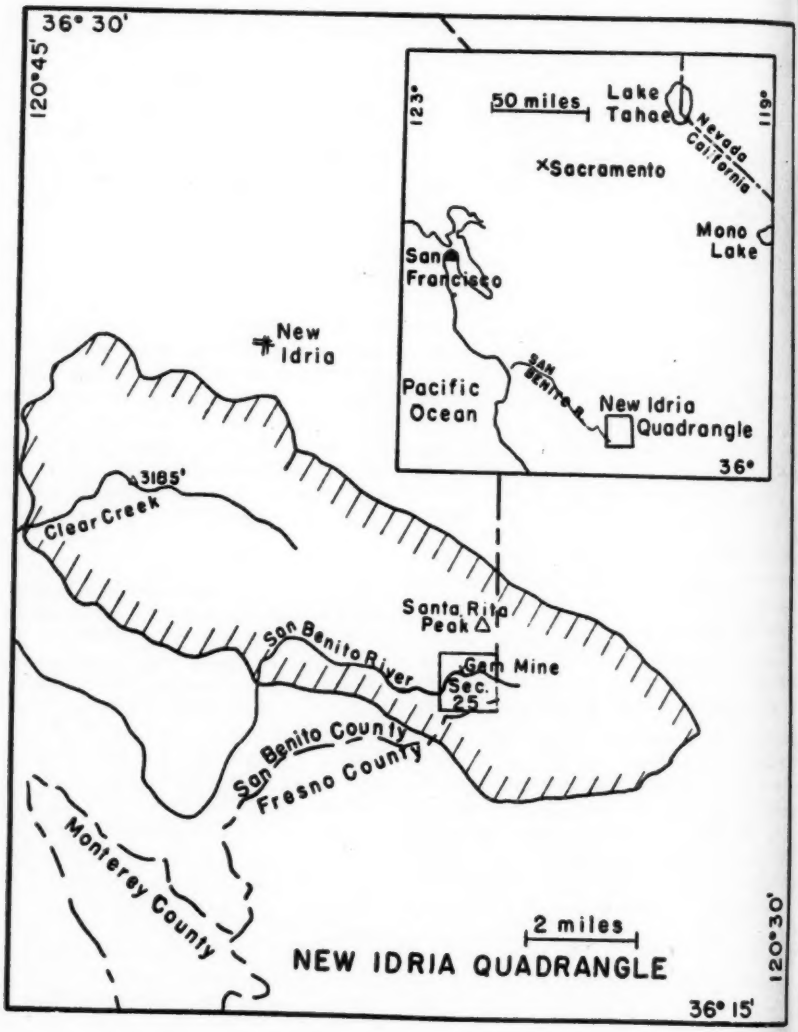

Fig. 1

Sketch map of the New Idria Quadrangle showing the outline of the serpentine area as mapped by Eckel and Myers (7).

MINERALS OF THE SERPENTINE AREA IN SAN BENITO COUNTY, CALIFORNIA

A. PABST

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Serpentine and related ultra-basic rocks occur in California in two belts. One belt extends along the foothills and lower western slope of the Sierra Nevada. Another belt extends northward through the coast ranges from Santa Barbara County for nearly 500 miles. In the north the two belts merge in the Klamath Mountains. Within these belts outcrops of ultra-basic rocks are discontinuous. The largest continuous bodies extend over scores of square miles. Many other bodies are too small to be represented on most geologic maps.

These serpentine areas are the sites of several kinds of commercial mineral deposits. The production of asbestos from serpentine has been unimportant in California but the value of the production of magnesite and chromite has totalled tens of millions of dollars. The mining of these materials has flourished particularly during wartime.

The magnesite in the California serpentines occurs almost entirely in microcrystalline veins, presumably formed from alteration of the enclosing rock. Macrocrystalline magnesite is rarely seen. In many places the magnesite is intimately intergrown with fine grained silica. Other minerals are mostly lacking.

Chromite is even more characteristic of the serpentines. It occurs in grains scattered through the rock as a minor constituent, but in many places it is found in greater concentration. Chromite prospects are innumerable. Production of 150 tons or more has been recorded in over one hundred locatities. The distribution of chromite mines and prospects has been shown on a state map (1) which also shows the "areas known to be under lain by chromite-bearing ultra-basic rocks."

Certain non-commercial mineral deposits in the serpentine areas are of special interest to the mineralogist or mineral collector. Most varied in their mineral assemblages are the deposits of calc-silicates and related minerals. In many places these are found as lenses, kidneys or contorted veins of crypto-crystalline material. Many of the so-called jade deposits in California that have received publicity from time to time are crypto-crystalline garnet or idocrase (californite). About ten years ago an authentic occurrence of nephrite jade was reported from Monterey County (2) and lately jadeite has been found along Clear Creek in the serpentine area of southern San Benito County (3).

In a few localities the calc-silicates within the serpentines are developed in drusy veins in which a variety of well crystallized minerals may be found. One such locality, near Georgetown in El Dorado County, California, has been described by the writer (4). The mineral assemblage there includes idocrase, grossular, diopside, clinochlore, prehnite and tremolite. The idocrase is by far the most abundant constituent and has been found in a great many colors. A fine green variety was taken by the claim holder to be emerald. Bolstered by the hope of finding more "gems", he also supposed the clear colorless garnets to be diamonds, he dug many prospect pits exposing these interesting minerals. The El Dorado County deposits are rather similar to those of the Black Lake Area, Quebec (5) and those near Eden Mills in northern Vermont.

By far the most famous mineral locality in San Benito County and one of the most famous in California is the so-called

"Gem Mine." Here benitoite, $BaTiSi_3O_9$, was discovered in 1907. This mineral is of special interest because it is found in beautiful blue crystals that may be cut into handsome gems. The crystals were the first known representatives of the ditrigonal-dipyramidal, 6m2, class and the mineral has not been found in any other locality. Benitoite occurs together with two other titano-silicates, neptunite and joaquinite. These minerals are encrusted with or entirely enclosed by natrolite which is the chief constituent of the thick veins in which these minerals occur. These veins traverse a block of Franciscan metamorphic rocks a hundred yards or more in extent entirely enclosed within the serpentine. These rocks contain glaucophane and related amphiboles but are so impregnated with natrolite in the veined zone that they scarcely resemble the glaucophane schists associated with serpentines elsewhere in the Coast Ranges.

Benitoite was named by Professor Louderbeck and its occurrence described by him in a paper (6) which the late V. M. Goldschmidt considered to be the best description of a new mineral ever written. Not only were the composition, form and properties of the new mineral recorded and its relations to the associated minerals and rocks discussed with great care, but etch figures were studied also to ascertain the symmetry. Where no general forms occur on crystals this was the best method for establishing symmetry at the time benitoite was described. Later study of the crystals by others by means of x-ray diffraction confirmed assignment of benitoite to the ditrigonal-dipyramidal class.

Though Professor Louderback wrote such an excellent account of benitoite and its paragenesis he made no mention of any noteworthy mineral occurrences in the nearby serpentine. Cinnabar deposits, mostly associated with zones of silica-carbonate rock, occur at many points in the serpentine and on its flanks. The famous New Idria deposit lies along the north edge of the serpentine about six miles from the Gem Mine (7). It was discovered in 1853 and is second only to New Almaden among North American quicksilver producers. In spite of this the serpentine area of about 50 square miles has not been well explored. It is a rugged, nearly roadless country with summits reaching 5,000 feet and habitations limited to the few sites of active quicksilver mining. In the southeastern part of the area, for many miles around the Gem Mine, there have been no permanent habitations whatever. In 1907, also, there existed no topographic maps of this region and access could be gained only by wagon or on horse-back. No wonder then that Professor Louderback in his excellent account of benitoite and its paragenesis made no mention of mineral deposits in the surrounding serpentine.

Soon after the discovery of benitoite a small body of syenite was found just south of the serpentine about three miles from the Gem Mine (8). A few years later (9) an analysis of the rock was published and the very large crystals of amphibole which characterize it were recognized as being the variety barkevikite. Following this there were no further reports of mineralogical or petrographic interest from this area for several decades.

About 15 or more years ago, following the rise of mineral collecting as an important hobby in California, mineral collectors began to visit the area. Most of them were secretive concerning their finds and one well-known collector even gave false information as to the source of melanites from this area, suggesting that they were from a locality in Calaveras County, about 150 miles distant and in an entirely different geologic setting. From time to time reports of various interesting mineral finds reached the writer and a few students and others brought in specimens. Finally some sketchy accounts of some of these finds appeared in print (10, 11, 12) and a little over a year ago the Berkeley mineral dealers, Minerals Unlimited, offered for sale specimens of perovskite, perhaps the most striking of the newly found minerals of the Gem Mine vicinity. Even so no information was available on the nature of the varied mineral deposits of the area. It seemed

that none of the collectors ever noted the location of a find on a map or paid any attention to the rocks round about.

Under these circumstances the writer welcomed an invitation from Mr. C. W. Chesterman of the California State Division of Mines to spend a few days in the field in the company of a guide, Mr. Carl "Buck" Bleifus, who would be able to lead us to some good collecting localities. Thorough preparations were made for the trip. Excellent topographic maps and aerial photographs are now available covering the entire area of interest (13). These were secured, together with a photostatic enlargement of part of the New Idria Sheet to a scale of about three inches to the mile. Now better information on the geology of the region was also available. The report on the quicksilver deposits of the New Idria District by Eckel and Myers (7) contains a geologic map on a scale of 1/48,000 covering the entire serpentine area of southern San Benito County. This was mounted for field use.

Even in the automobile age access to the Gem Mine and its surroundings is not easy. State highway 180 may be followed to Panoche, about 30 miles from the area of interest. From there a well travelled road leads to the region of the mercury mines around New Idria. (Fig. 1). Beyond this the road is not regularly maintained. It is said that a bulldozer was run over it during the war to provide access to some remote prospects but travel on this road is somewhat precarious and not to be recommended in bad weather or for those who use modern "juke-box" automobiles. For anyone wishing to make more than the briefest visit to this area camping out is essential since the drive from the nearest place where accommodations may be had requires several hours even under the most favorable circumstances. The tough Division of Mines truck in which we travelled was excellently adapted to the terrain and we reached our goal without difficulty.

In spite of darkness we found a fine camping spot, a hundred yards from the abandoned cabin belonging to the Gem Mine, on the flat along the San Benito River. Next morning we found the small stream frozen. While it was late in April, even at latitude 36° the altitude of nearly 4,500 feet had its effect. This is within a mile or two of the headwaters of the San Benito River whose flow is a mere trickle in dry seasons. Though surely not contaminated from human sources the river water is not suitable for drinking because it is practically saturated with magnesium salts. Visitors must bring in water for drinking and cooking.

Collecting at the Gem Mine is no longer inviting. Though all the characteristic minerals of the locality are still to be found the easily obtainable benitoite has long since been removed and it is now difficult to get good specimens of it at the source. Our attention was devoted chiefly to the numerous other deposits of well crystallized minerals nearby. In two days we visited at least eight distinct deposits within a mile of the Gem Mine which is located in the NE¼, Sec. 25, R. 12 E.; T. 18 S.; MDBM.

Areas of serpentine are generally barren. At the Gem Mine the brush on the area of metamorphic rocks is very dense but round about the brush is mostly rather sparse with pine trees scattered here and there, only those in the river valley reaching stately proportions. There are no meadows, in fact, grass is confined to a few small patches. Over much of the area the serpentine has broken down to a fine flaky or powdery white cover that mantles the slopes and makes walking most arduous. This material apparently will hardly support vegetation at all. It covers numerous tracts acres in extent, white barrens referred to by our guide as "caliche." The deposits of calc-silicates and associated minerals are scattered about in the weathered serpentine. They are not enclosed in recognizable bodies of Franciscan schist. In some places the calc-silicates are found directly in contact with sheared serpentine, mostly as lenses or veins of short extent. Elsewhere they are developed in cracks or vuggy portions of small bodies of chlorite rock within the serpentine. A few spots are worthy of special mention.

In the SE¼ of section 25, nearly half a mile south of the Gem Mine a prominent mass of pale greenish-gray chlorite rock rises through the debris mantle due east of the sharp turn in the river at the elevation of 4,175 feet and about 400 or 500 feet above this level. Parts of this chlorite rock are laced with cracks. These are mostly filled with black garnet (melanite). The melanite both from here and from another nearby locality (G-3.7; n-1.86) gave a strong qualitative test for titanium. Where there are open spaces in the cracks fine dodecahedral crystals can be seen. It is in this situation that the aforementioned perovskite crystals are found. They are black and brilliant in luster, in places almost metallic. The crystals, dominantly cubic, usually also show the dodecahedron and octahedron and small faces of various other forms, mostly (023), (034), and (045). These crystals are, in the main, larger than the garnets, reaching dimensions of ½ inch or more on edge. Associated with the perovskite and melanite is a very little idocrase in fine black crystals practically identical in color and luster with the dominant melanite. It is by far the darkest idocrase ever seen by the writer.

A month or two after returning from the field the writer received for examination from Mr. John B. Jago a specimen from the perovskite locality just described which had been bought from a San Francisco mineral dealer. In addition to the minerals mentioned above this specimen contained one or two small roughly octahedral, translucent, honey-colored crystals of brilliant luster. A fragment was found by the Berman balance to have a specific gravity of 4.2 ± 0.2. Its refractive indices were found to be very high, but birefringence very low. These properties indicated perovskite but since it seemed surprising to find two such dissimilar varieties of this mineral in the same veins an X-ray powder diffraction pattern was prepared. It turned out to be indistinguishable from that of the commoner black, almost metallic, perovskite from these veins. Upon reexamining the specimens earlier collected it was then found that some of the clusters of black crystals cover or enclose lighter transparent parts, and gradations may occur. Comparable variations in the color and luster of rutile have been shown to be due to departure from the simple two to one ratio of oxygen to titanium, the blackness and metallic luster of many rutiles being attributable to a slight deficiency of oxygen (14).

Just below the perovskite locality several cavernous boulders of chlorite rock are strewn about in the light flaky serpentine debris. The numerous openings in the rock are studded with minute octahedrons of magnetite. Among these are found a few thick tabular crystals of ilmenite with dimensions of ⅛ inch or more together with a little coarse calcite. The principal forms on the ilmenite crystals are [0001], [10$\bar{1}$0], [50$\bar{5}$2], [22$\bar{4}$1], [22$\bar{4}$3], accompanied by small faces of a great number of other forms. A few hundred feet farther down the slope colorless grossular (n-1.75) and pale idocrase very similar to the varieties found near Georgetown were collected from float.

Less than half a mile west of the perovskite and ilmenite localities a steep densely wooded hill rises nearly 500 feet above the San Benito River, contrasting sharply with the general barrenness of the country. The upper part of this hill is made up of barkevikite syenite. This is one of two small bodies of this rock within the serpentine shown on the Eckel and Myers map. The southern contact of this syenite body against the serpentine is situated at the very top of the hill. As usual the actual contact was covered though its position could be located to within a few feet. House-sized boulders of syenite have rolled down the slope and lie along the river for several hundred feet. The syenite here resembles that found long ago on the southern flank of the serpentine. It is coarse grained with long bladed crystals of barkevikite the most conspicuous mineral. These are commonly an inch in length and in places several times that size. Some phases of the rock carry up to 75% or more in barkevikite. Albite veins several inches thick, carrying a little muscovite, traverse the syenite.

The titanium rich minerals described above occur near this syenite and one might be tempted to postulate a genetic connection. One objection to this may be mentioned. Though no analysis of the syenite in section 25 is available the very similar syenite on the flank of the serpentine only a little over two miles away has been analyzed (9). It contains but 0.42% TiO_2, less than the average TiO_2 content of the earth's crust.

The calc-silicate deposits elsewhere in the serpentine near the Gem Mine carry garnet and diopside as the most abundant minerals. The diopside is white or exceedingly pale colored and usually in thin bladed crystals (11). The garnets are of several varieties. Besides the black melanites which are everywhere dodecahedral with, at most, narrow truncations of the [211] trapezohedron, green garnets are most common. They also commonly show both [110] and [211] but the latter is never dominant. Some are the gem-like variety of andradite that has been called topazolite. In one outcrop in the NW¼ of section 25, on the crest of the ridge about 200 yards northwest of hill 4461, these green garnets, emplanted on or intergrown with long prismatic diopside, are found to be mere shells, some broken and revealing the hollow interiors.

The easternmost of the calc-silicate localities visited lies in Fresno County, about a quarter of a mile east of the county line which coincides with the east line of section 25. It is in Sec. 30, R. 13 E.; T. 18 S.; MDBM, about 50 feet above the San Benito River on the left (south) bank at an elevation of about 4,600 feet. It is a shallow prospect pit on an open slope. The principal calc-silicates here also are green garnet and white diopside. They are associated with very pale colored chlorite and varicolored idocrase with dark garnet in vein-like development within compact diopside. This assemblage is in direct contact with pale colored, antigoritic, serpentine. The entire extent of the deposit, whose limits cannot be seen precisely, is not more than a few yards. In this place a very rare variety of a common mineral may be found. Sparsely scattered about on the diopside and garnet are small bright cubes of magnetite. The largest do not exceed two millimeters in diameter but, even so, they are large enough that there is no doubt about the crystal form. Though an occasional octahedral face can be recognized the dominant form is always the cube. This habit is most unusual; "Dana" (15) lists only two occurrences. To make doubly sure of this surprising find the ordinary identification tests were supplemented with a single crystal X-ray rotation pattern. It proved beyond doubt that this is perfectly normal magnetite.

Elsewhere in the vicinity other varieties of magnetite are found. At the long abandoned Windy Mountain Claim in the NE¼ of section 25 about half a mile east of the Gem Mine there is an extended patch of chlorite rock. In the open spaces of this rock may be found three members of the spinel group, magnetite, pale translucent spinel and dark almost adamantine spinel, all in simple octahedrons, mostly grouped in clusters. Associated with these are nearly colorless apatite and greenish yellow sphene. All except the apatite occur in small but excellent crystals.

Near its headwaters the debris in the bed of the San Benito River is in many places cemented to a rocky mass. In one spot just below the 4,500 foot contour this material is crusted and broken, making a small waterfall with a drop of several feet. A few hundred yards east of this point, near the east line of section 25, the rocky stream bed material consists almost entirely of magnetite crystals and fragments with a minor amount of serpentine bits firmly held in the fine-grained carbonate cement. The largest magnetite crystals here reach dimensions of an inch or more. Those on which the crystal form can be distinguished are invariably bounded principally by the faces of the dodecahedron. The source of the magnetite cannot be far away for many of the crystals are rather well formed and show little sign of wear but the difference in habit leaves it certain that they are not derived from the nearby magnetite occurrences *in situ* previously described. The exceedingly fine-grained cement was

identified by chemical and X-ray tests to be dolomite.

Though the mineral deposits mentioned above were the principal objective of our trip we did, of course, visit the Gem Mine. The open cut and caved workings are still quite a gash in the landscape but there has been so little activity at the "mine" for many years that one cannot even discern a path to it through the dense brush. The minerals for which the locality is noted can still be obtained, though the benitoite which was once secured here in large quantity is now hard to find. A great deal of the peculiar variety of natrolite which is the matrix of the titanosilicates here, can be seen. It is a more or less granular mass of nearly equidimensional crystals quite unlike the widely known acicular to fibrous natrolite. Neptunite in splendid glistening black prisms is easily found. Close inspection of specimens of neptunite often reveals minute honey-colored crystals of the very rare joaquinite. Several specimens of these minerals were collected and one of the members of the party even found a pretty fair piece of benitoite. In the open parts of the natrolite may be found small tufts and coatings of the hairy to feathery variety of amphibole often referred to as "byssolite." This material was checked by x-ray powder pattern and optical examination. The crystals are so thin and often coated that optical properties cannot be accurately determined. The mean index is variable but close to 1.66 in some crystals and the bluish green color shows gradations within a single crystal in those few that are large enough to permit such observation. This amphibole is presumably close to glaucophane.

Altogether there are found in the several mineral deposits of section 25 at least seven titanium minerals: benitoite, neptunite, joaquinite, perovskite, ilmenite, melanite and sphene. Some collectors have also reported rutile. This was not seen by the writer but it may be that still other titaniferous minerals are present. One might, for instance, expect to find some titanium in the very dark idocrase seen in small amount with the melanite in at least two places. The association of such a variety of titanium-bearing minerals in rocks which themselves are not highly titaniferous suggests that certain phases of the mineralization involved the local introduction of titanium as a characteristic feature.

On the third day of our sojourn we headed homewards, but not until we had taken a short hike to the top of Santa Rita Peak, a scant mile northerly from the Gem Mine and only 86 feet lower in elevation than the top of San Benito Mountain, the highest point in the county. Santa Rita Peak is an excellent vantage point from which to get a view of the surrounding country and, indeed, of the whole geographic setting. Our visit was favored by fine visibility so that we were able to survey ridge upon ridge of the coast ranges with the ocean fog dimly seen beyond and the entire width of the broad San Joaquin Valley to the far Sierra Nevada in the east. On the south flank of the peak we found a small area of metamorphic rocks entirely surrounded by serpentine and not included among the patches of such rocks shown on the map of Eckel and Myers (7). This area of metamorphic rocks lies at an elevation of 4,950 to 5,100 feet and is less than an eighth of a mile in extent. The metamorphic rocks are mostly fine-grained glaucophane schists with some sparsely scattered quartz and albite veins. In the lower part of the schist area there are several small patches of natrolite. The largest of these seen has outcrop dimensions of about half a foot by two feet. The natrolite is of just the same peculiar type as that at the Gem Mine and the whole patch looks as though it might be a miniature of the benitoite deposit less than a mile away. In the openings of the natrolite are found the familiar hairy to feathery tufts or coatings and some material of this sort is entirely embedded in the natrolite. Careful search failed, however, to reveal any neptunite or benitoite.

On our homeward journey we made one more mineralogical stop to investigate a locality which has received a great deal

of publicity of late (3). A little over a year ago jadeite was found in large boulders along Clear Creek, a tributary of the San Benito River. Several people have claimed the credit of discovery (16, 17, 18). None of them have been specific about the locality. Clear Creek drains several square miles of the northwestern part of the serpentine in southern San Benito County. There is a road along the creek for several miles in this area so that access to the region is relatively easy. Boulders of jadeite or jadeite-bearing rock are found in and near the creek bed for several miles and we obtained some magnificent specimens. By systematic search Chesterman and Bleifus also found jadeite in outcrop on the left bank of the stream a short distance below the elevation marker 3,185 feet indicated by a sign along the road. Subsequently other outcrops were found.

While scouting for jadeite along a small left bank tributary of Clear Creek in the west half of section 12, R. 11 E., T. 18 S., MDBM., the writer came across two small garnet occurrences in the serpentine terrain at an elevation of about 3,200 feet. One of these showed black garnet similar to the melanites found eight miles to the southeast in the Gem Mine region. The intervening area is uninhabited and nearly roadless. It seems not unlikely that search would reveal many more interesting mineral occurrences in this region.

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THE MONO COUNTY ANDALUSITE MINE

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Geographic and Geologic Setting

The Mono County Mine, owned and operated by the Champion Spark Plug Company of Toledo, Ohio, is situated in west-central California on the western flank of the White Mountains about 20 miles south of the California-Nevada State Line. The highest peak, White Mountain (elevation 14,201), is only a few hundred feet lower than Mt. Whitney. The mountains are snow-covered above the twelve thousand foot level for much of the year, a fact which was instrumental in the naming of the range. Geologically the range contains an almost complete Paleozoic section from early Cambrian in the north part to undifferentiated Carboniferous in the south. Quartz monzonite and granodiorite intrusives and basaltic extrusives are common throughout the entire range. The area north and south from White Mountain Peak for a distance of forty miles is an uplifted peneplain, standing at over 12,000 feet above sea level. Little prospecting has been done in this region, and locally it is believed to be a mineral treasure house where gold nuggets as large as walnuts cover the ground. These legends are helped by the early placer mining at the extreme southerly end of the area where gold in paying quantities was found. The region is extremely rich in its number and variety of mineral species and notably poor in commercial mineral concentrations. Small showings of gold and silver ore have been in extremely rich pockets along the western flank of the mountains but have shown little value with depth. Hundreds of small prospect holes dot the west face of the range, each representing vanished dreams of great wealth. A few hopeful souls still try every year to find the well-hidden lodes which still remain a riddle as far as they or anybody else is concerned. Only two metal mines have been a commercial success in the entire range; the Indian Queen, a silver mine located in the extreme northern end, and the Cerro Gordo, a silver, lead, zinc mine at the southern end. Both properties are now idle, although attempts to re-open them are made from time to time.

History of Discovery

The presence of andalusite in the White Mountains was first mentioned by Dr. Adolph Knopf (1). A group of prospectors had located a white quartz outcrop showing patches of blue lazulite which they assumed to be silver bromide. Knopf was asked to check the deposit and identified the blue mineral as lazulite and not silver bromide. He also noted the occurrence of masses of low grade andalusite in the vicinity and described these briefly in his paper. In 1919 the late Dr. J. A. Jeffery, then president of the Champion Porcelain Company of Detroit, Michigan, was seeking a natural source of insulating material suitable for the manufacture of heat and shock resistant porcelain. Noting that the White Mountains held a possible source of such material, the lazulite claim was investigated and low grade andalusite was found nearby, but not in sufficient concentration to warrant mining. That night, camping in a wash below the outcrop, Dr. Jeffery crawled into his sleeping bag, found the usual hard rock in the small of his back and cast it out into the night, thinking at the time it was very heavy for its size but that sleep was more important than rocks. In the morning, to his surprise, his unwelcome bedfellow of the night before was a piece of high grade andalusite, quite different from anything that he had seen on the lazulite claim the day before. This discovery stimulated further exploration up the wash, studying the float as the party moved upward. About a mile farther the wash was

Fig. 1
View looking north showing the Andalusite mine cliff and dumps (near center of photo.).

blocked by a steep cliff and the party was forced to leave the wash and work their way towards the summit of the cliff. No further float was found, but just below the summit of the cliff on its eastern face they observed material resembling crystalline andalusite. While two of the party held the rope, Dr. Jeffery was lowered down the face of the cliff and confirmed the existence of ore similar to the first piece of float. Such was the discovery of the Mono County Mine, the only known commercial source, even today, of high grade andalusite in North America.

Occurrence of the Ore

The andalusite occurs in massive quartzite. Its age is believed to be pre-Cambrian, but there is no positive evidence to establish this fact. Comparative lithology and degree of metamorphism are the criteria used to establish the age. The western face of the White Mountains has been deeply eroded by deep canyons with intervening precipitous cliffs and hogback ridges, the two latter features formed where resistant quartzite contact resistant highly metamorphosed clays. Over five miles of contact often one-half mile wide is exposed on the surface. The ore is concentrated along a pre-mineral fault zone, although minable concentrations of andalusite are scarce. This fault strikes N 20°E and dips steeply SE. The elevations of the contacts vary from 5,500 to almost 11,000 feet; the mine is situated at 9,500 feet. The only access to the workings is by a steeply winding trail, all ore and supplies being moved by pack mules. In many places the trail winds along faces of steep canyons where it is possible to look down a thousand feet or more from the hurricane deck of a mule. Despite these hazards, more than 25,000 tons of high grade ore moved down this trail with the loss of only three mules. The most favorable concentration of ore occurs in a layer near the base of the cliff. This layer ranges in thickness from 5 to 25 feet, and has a maximum vertical height of about 100 feet. Lenticular bodies of ore penetrate the cliff as far as 100 feet, these lenses being controlled by the dominant joint system in the quartzite. In many sections the ore shows profound alteration by hydrothermal solutions and surficial weathering. Strangely enough, there is practically no high grade andalusite float below the outcrop, although cloudbursts are a common occurrence during the summer months. The lower portion of the range consists of a series of stream conglomerates, argillites and phyllite, all exhibiting metamorphism to a greater or less degree. The pebbles of quartzite in the conglomerate show sharing and squeezing. Minor amounts of pyrite are present and an occasional grain of gold may be seen. The phyllites and schists, which lie directly above this series contain lenses of intergrown magnetite, actinolite and occasional pockets of argentiferous chalcocite. Above the mine at an elevation of 11,000 feet is a small outcrop of chalcopyrite which was worked by an early-day prospector who had more courage than good sense. He would have had to train eagles to fly the ore out. He was a rugged individualist who lived in a small lean-to high above the mine and once killed a wildcat with a prospecting pick when the animal tried to crawl into bed with him!

Origin of the Minerals

The origin of the andalusite allows several interpretations, but the prevailing view is that it is primarily the result of deep-seated metamorphism of the quartzite, which probably once contained richly aluminous sedimentary beds. The lenticular ore bodies are confined to a pre-mineral fault zone in the quartzite, the majority of this rock being free of andalusite. Both rutile and zircon must have been present in the original sedimentaries for they are now widespread in the ore. The intrusion of a mass of quartz monzonite in later Jurassic time gave rise to both a high and low temperature phase of thermal metamorphism. Solutions containing fluorine, boron and phosphoric acid were introduced through channels in the ore, resulting in the formation of new minerals and extensive hydrothermal alteration of the existing ores. Continuous oxidization of large masses of pyrite resulted in the formation of highly acid

Fig. 2
East face of the Andalusite mine cliff showing workings along base of cliff. Top of cliff is 500 feet above working. Note camp in right foreground.

mine waters, which caused excessive leaching of the andalusite, forming large beds of various alums at the base of the cliff and charging the water of the intermittent stream below. Successive waves of hydrothermal solutions produced a succession of minerals, the earlier minerals providing the sources for the later ones. Pseudomorphs of quartz after andalusite are common, one section of the mine having a vein 4 feet thick of quartz pseudomorphs showing a rhombic cross-section. The last phase was supergene-forming, accompanied by the minerals jarosite, limonite, sulphur, hyalite and gypsum. This change has been a distinct advantage for mining as it removed much of the disseminated pyrite in the ore. Iron minerals lower the melting point of andalusite and render it unfit for ceramic purposes. Post-mineral lenses and veins of barren quartz were commonly found cutting the ore and could be removed without much difficulty. Along the contact large pockets of euhedral quartz crystals were often found, many being doubly terminated. Many new and unique problems were encountered during mining and production, and wholly orginal techniques were evolved to cope with each situation. All the ore had to be hand-sorted after being broken with a ten pound sledge, [invaluable training for postgraduate work in our better penal institutions.] Sorted ore was checked for purity by taking the average specific gravity. In this manner high silica content could be detected and avoided. The problem of blasting hard ore from the face of an almost vertical cliff and saving it before it disappeared into the canyon 2000 feet below resulted in the development of new drilling and shooting methods. Many times miners were fastened by cable to the cliff as they drove jackhammer drills into the ore. Blasts were at times spectacular and stray rocks would fall like rain on the camp. During one blast, a twenty pound chunk of rock swept the cook stove clean of all the dinner dishes and pots. The cook took one look at the mess, put on his hat and walked down the hill. The air was blue behind him as he voiced his opinion of people who would work in such a place.

Description of Minerals

Mineralogically the Mono County Mine is of compelling interest, not only for the number and variety if its secondary minerals, but also because the crystals of andalusite found there show a most unusual habit. Dr. A. B. Peck has described these crystals (2). The colors range from bluish gray through light gray to pale green. No pleochroic reddish brown andalusite was found in the deposit. A great number of x-ray powder patterns were taken of the crystals, which showed no deviation from the accepted structure of the unit cell, and the causes for the above variations are still a matter of doubt.

One mineral new to science, woodhouseite, was found in relative abundance in those sections of the vein where there were notable concentrations of lazulite Pseudo-cubic crystals were found implanted on the earlier minerals and were probably formed by the hydrothermal alteration of the primary phosphates. In one small section of a vug woodhouseite crystals were observed hanging from hair-like achroite. Several other secondary phosphates were found in minute quantities, but sufficient material for accurate determination could not be collected. In order to get to the area where these minerals occurred, it was necessary to hang by one hand to a very precarious footing on the cliff and try to poke out a specimen from a small vug with the other. If either hand were to let go of its hold, either of the specimen or the rock, the operation would be a complete failure. The prevailing tendency was to let the specimen go and save the body. For this reason the identification of the rare secondary minerals is still unknown.

The earliest recorded occurrence of crystallized augelite at the mine is also noteworthy. Massive cleavages of augelite had been noted in the ore for some time, but no crystals could be found. One cold December day, Dr. Dwight Lemmon was seated on a pile of muck and running

his fingers through it for want of something better to do. Both he and the author were deep in a discussion of augelite and wondering why the blankety-blank mineral did not crystallize. Dr. Lemmon felt a small object in the dirt, picked it up, and lo, there was a perfect augelite crystal. From then on it seemed as if augelite crystals were everywhere. Several hundred were found, some loose in vugs and some in a limonite matrix. Most of the crystals exhibited a wealth of new faces and many had inclusions of lazulite. All our miners were avid mineral collectors and after the shift was over spent much of their time hunting crystals. The only way the author could be sure of keeping any crystals for himself was to pop them in his mouth and carry them to a safe hiding place in that manner. Small masses of sapphire blue corundum were objects of intensive search, with the hope that a crystal would be found large enough to mount in a ring. None were ever found. The blacksmith did, however, grind some small masses in rough hexagonal forms, hoping to fool the collectors. Euhedral crystals of the minerals were found only in miarolitic cavities or in solution vugs in the veins. Hands were always reaching out for specimens, sometimes over your shoulder or into your collecting bag. In many cases the hand proved much quicker than the eye. Stuffing specimens in your mouth or your shirt was the only sure method of saving them. There were no dull moments collecting minerals at the Mono County Mine.

There were some 35 different mineral species found in the deposit, many of them common, but many noteworthy for rarity or form. It is possible to discuss only a few of these in this article.

RUTILE. Crystals of this mineral in complexly-twinned forms were found uniformly throughout the deposit. They varied in size from microscopic grains to euhedral crystals several ounces in weight. Where intense pyrophyllization of the ore had taken place, large euhedral crystals were found in this matrix. The best collecting spots were always on the edge of the cliff, and many a collector had watched a choice crystal slip from his hand and disappear into the void below.

AUGELITE. This phosphate was not only found massive in a large vein associated with lazulite, topaz, natroalunite and andalusite, but also well crystallized in a limonite matrix associated with wood-houseite, achroite and lazulite. Many of the crystals seem to have been under severe compressional strain, for if they were carelessly left in the sun for a few moments, they would explode with a sharp report and fly into dust. Many exceptional crystals were destroyed by blasts as there was no other way to explore the ground where they occurred.

FRANCOLITE. A fluor-apatite. Small curving crystals of this mineral were found in vugs associated with massive augelite. Dahllite was also noted.

STRENGITE. This hydrous iron phosphate occurs in a few sections of the mine where extensive replacement has taken place. No crystals wre observed but small masses of pale red to lavender color were found along fracture planes in a very complex ore. This mineral has a tendency to lose color quickly due to dehydration in the desert air.

CORUNDUM. Though not a rare mineral, corundum at the Mono County Mine occurred as deep blue sapphire, either in subhedral grains or basal plates, some of the latter being several inches in diameter. At one location in the mine, corundum was found in solid masses, several pounds in weight. It had a beautiful blue color, but, unfortunately, the masses were opaque.

TOPAZ. This mineral, like the corundum above, never formed in euhedral crystals of any size. It was either massive or in small grains, and of no value. Along the border of one mass of ore there was a zone of massive topaz ten feet thick. It presented a very difficult drilling problem because of its extreme hardness, and special techniques had to be devised to overcome it. One spot in the zone was reserved for visiting drill salesmen to demonstrate the value of their drill steel. They never could understand why the gauge wore off the bit

so quickly and why the drill would not penetrate the rock. The air would be full of lurid remarks about White Mountain rocks and disgusted salesmen would go down the trail wondering what in hell was the matter with their steel. P. S. We never told them.)

DIASPORE. At the base of the cliff on its western side was a zone of high temperature thermal alteration, where the andalusite in the region had been changed to diaspore. Considerable ore was mined here for use in kiln furnaces. No euhedral crystals were found, but there was an abundance of cleavage plates one to ten inches in length. Some plates formed stellate groups, with the mineral taking on a concretionary form. A few boulders with closely intergrown rutile, diaspore and indicolite were found as float near the veins.

ACHROITE. Masses of hair-like white tourmaline were found in many vugs in sections of the deposits where there had been extensive hydrothermal action. Often minute crystals of woodhouseite and lazulite would be hanging from the fibers of achroite like ornaments on a Christmas tree. All the boric acid present must have formed tourmaline for no evidence of dumortierite was ever found at the mine.

BARITE. Some of the barite groups found in cavities in the quartzite were outstanding. One such cavity contained a superb group of long terminated prisms, several being over twelve inches long. This group was smuggled out by one of the miners and, when last heard from, was hidden in a chicken house. There have been later rumors that it may soon be missing from that location.

WOODHOUSEITE. This sulphate-phosphate member of the beudantite group was the new mineral species found in relative abundance throughout the deposit. It was formed by hydrothermal alteration of lazulite which furnished some of the chemical constitutents. The mineral was first observed by the author in a vug in a mass of sericite and the pseudo-cubic form of the crystals, suggested that it might be fluorite. Upon closer examination, the difference in crystal form was observed and determination of the indices of refraction more or less confirmed what had already been suspected, that a new mineral species had been found. First called Mineral X, it was finally described and named by Dr. Dwight Lemmon ([3]). The crystals range in size from a faction of a millimeter to several millimeters in cross-section and are often curved, striated or ethched. As a general rule the crystals have a slightly yellowish color, are opaque, and are often coated with crusts of limonite. Large groups of crystals are uncommon and only one or two were found. In massive form strontium bearing natroalunite easily may be mistaken for woodhouseite. The natroalunite forms rough wedge-shaped crystals and is never found with woodhouseite, which is usually associated with quartz, augelite and lazulite. Minute inclusions of rutile often color the woodhouseite a reddish brown. At the present time that portion of the mine where the best specimens of this mineral were found is covered by a rock slide and the dump would be the best source for material.

LAZULITE. This iron, magnesium, aluminum phosphate was one of the commonest minerals in the ore but, despite its abundance, only one large euhedral crystal of the mineral was ever found. The mineral occurs in solid masses as well as in disseminated grains in all parts of the contact zone. It is not suitable for ornamental purposes, as it all shows evidence of weathering and surficial alteration. Scorzalite, the iron rich member of this group, was detected in some of the outcrops below the mine. It was closely intergrown with specular hematite and ilmenite.

It is impossible in a short article to completely cover the mineralogy of the mine or to describe all the varied occurrences of the minerals. Each section of the veins opened up entirely new combinations of minerals and it is very possible that many new species were overlooked or were destroyed by blasting. The last work done on the deposit was on the diaspore veins, about 2500 tons

of ore being mined and sorted. A number of large vugs filled with pyrophyllite were uncovered. Scattered about in the pyrophyllite were numbers of large, euhedral rutile crystals, but by this time every miner was intent on making his own collection and the crystals disappeared like dew before the morning sun. The rutile was highly spectacular and more could be uncovered if active mining were in progress. It must be obvious to the reader of this article that the whole contact area presents unrivaled opportunities for collecting and research, but this is only possible when the mine is in operation. Even as I close this description, I am wondering what would be the chance of uncovering another rutile pocket if I made a trip to the area this summer.

AUTHOR'S NNTE: The author wishes to express his sincere appreciation to Dr. Robert W. Webb for the critical reading of the manuscript.

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BORATES OF CALIFORNIA

M. VONSEN

Business man (farm products) in Petaluma, California; amateur mineral collector.

The story of the discovery of borates in California is one of romance and adventure. In fact, one might say it is comparable to the gold rush of '49 and, although on a much smaller scale, possessing the same spirit of adventure which caused men to endure untold hardships in the early prospecting for boron minerals in the mountains and hills of northern California. No less arduous were the later discoveries, farther south in a land of sage and desert where the summer heat and lack of water brought tragedy to many intrepid prospectors in a region civilization had hardly touched.

Borax Lake Region

The discovery of borates in the United States was first reported in a letter by Dr. John A. Veatch on June 28, 1857, to the California Borax Company, for whom he was scouting the northern part of California in search of borate deposits of commercial importance. Actual discovery was made by Dr. Veatch in January, 1856, in Tehama and Lake Counties. This was of borax, a hydrous sodium borate, which seems to have been the only borate occuring in commercial quantities in that region.

One of the first occurrences of borax was found in solution in the waters at Tuscan Springs, Tehama County, later referred to as Lick Springs, and eight miles east of Red Bluff. By evaporating the water in an artificial pool, crystals of this mineral were found. This discovery in 1856 is a memorable date that will go down in history as the forerunner of other discoveries that later led to one of the state's largest industries and the world's greatest production of borax and boron products.

Dr. Veatch found other springs containing dissolved borax during 1856 and 1857, but these were all minor occurrences. It did, however, help in maintaining his interest and enthusiasm to continue his rather difficult undertaking. He traveled many weary miles on foot and horseback in rough and rugged country, very sparsely populated. All occurrences were carefully examined, but proved too small for production. Hunters and early settlers told him of numerous mineral springs of sulphur and bitter waters, of a soda lake, an alkali plain, a hill of white powder, and a sulphur deposit. Such reports spurred Dr. Veatch on to greater efforts to supply an urgent need in the United States.

From what was described as a white hill (now known as Sulphur Bank, Lake County) he crossed a steep range of hills to the west and went down to Alkali Lake also called Lake Kayso by the Indians but later named Borax Lake. Alkali Lake covered an area of fifty or sixty acres about two miles west of Sulphur Bank. He also examined another little lake of about twenty acres known as Hachinhama Lake about four miles west of Borax Lake at the base of Mt. Konocti near Clear Lake. The brine of this lake was found to be rich in borax; in fact, it carried a higher percentage in solution than Borax Lake. Borax Lake is situated about 114 miles north of San Francisco by road on a peninsula forming a small triangular valley surrounded by hills. On two sides the hills join at a point north of Borax Lake and project well into Clear Lake. At the south end of the valley are some low hills composed of quite recent volcanics, consisting of much obsidian and basalt. Basalt also caps some of the other surrounding hills.

Borax was recovered from Borax Lake for a period of four or five years, from 1864 to 1868, and during that time supplied the whole country's requirements. When production ceased, it was said to be not on account of the depletion of borax but because of mismanagement. This is perhaps true, as the lake is still rich in borax. Crystals of borax recovered from the mud were the source of all the borax. Tons of perfect crystals up to four or five inches in length were taken from the mud.

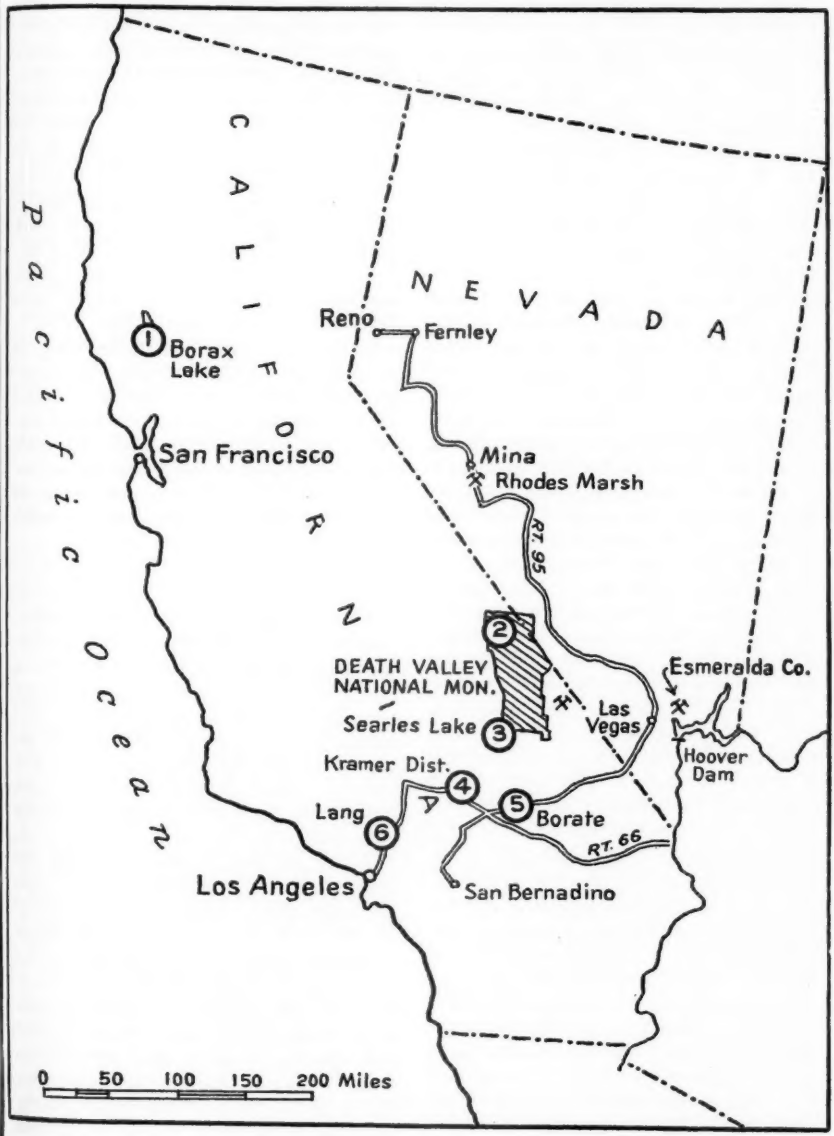

Fig. 1

Map showing principal borate localities in California (numbered) and Nevada (mine symbols).

Only a few in existence today; they have lost their luster but are perfectly developed.

After a series of dry years the lake becomes a vast pool of mud completely covered with an encrustation of salt. It was found that by the use of improvised skis, made of 1 x 6 inch boards, about six feet in length, and well fastened to the shoes, it was possible, with extreme care, to walk over the surface of the lake. In the center of the lake there was a bed of trona, hydrous sodium carbonate, an acre or two, in extent, and beneath three or four inches of a viscous, brownish colored brine. In places this trona had been arched in hips, roof fashion, extending well above the brine. On the under side of this arched trona, beneath the heavy brine, occurred the rare mineral teepleite, a hydrous sodium borate and chloride. It is colorless to light buff, well crystallized in tetragonal crystals of simple habit, and forms clusters of crystals replacing halite in part or in whole. In the latter case the replaced cubes of halite are plainly noticeable. This is the only known occurrence of teepleite. It was found and collected in August, 1934, this being about the only year the lake was reported well dried up since 1861; although in 1936 some teepleite was found with halite on trona, desiccation had not proceeded sufficiently to permit the growth of teepleite crystals There may have been other dry years in between but they have not been recorded.

Northupite, a chloride-carbonate of sodium and magnesium, in small octahedral crystals up to a half millimeter in size was found in considerable abundance embedded in trona near the western shore of the lake. Gay-lussite, in small crystals up to a millimeter in size was also found in this trona, along with orthorhombic crystals of pirssonite. Gay-lussite and pirssonite are hydrous carbonates of sodium and calcium. Glauberite, a sulfate of sodium and calcium, was reported as having been found by Silliman in flattened tables in a boring forty foot deep in the blue clay.

Innumerable small crystals of borax, an inch or smaller in size, were found in the shallow mud on the east side of the lake and also scattered lightly through the mud elsewhere around the lake. Fine glassy groups of borax crystals attached to trona a hundred feet or so offshore on the west side were quite common. They were interesting specimens, since the beautiful glassy crystals showed off in good relief against the buff colored trona.

After operations were discontinued at Borax Lake in 1868, activities were transferred to Hachinhama Lake where a sufficiently large volume of borax was recovered from the brine to supply American requirements from 1868 to 1873. The project was then abandoned on account of overproduction from enormous borate deposits in Nevada and, later Death Valley, where large beds of ulexite were then being worked. Thus ends the first chapter in the production of borax in the United States, after which all operations were transferred to the Death Valley region.

Death Valley region

Death Valley, situated in Inyo County, California, near the Nevada line, was first mentioned in the year 1849. It was during that year that the Bennett group of pioneers, headed for the gold fields of California, had entered the valley, as this appeared to be the easiest and quickest route. Their decision to cross Death Valley was taken after much consultation with others of the main Bennett party, resulting in their withdrawal from the main party which continued on a more southerly route. Little did they realize the hardships and tragedy that lay ahead.

William Lewis Manley, member of the group, in his book "Death Valley" (1) narrates their tragic experiences in crossing Death Valley, due to lack of food and water and other items of necessity and resulting in death to some members of the party. After several months in the valley, and suffering most of the tortures and hardships human flesh can fall heir to, they were finally led across Panamint Mountain and a hundred miles of desert by Manley to white settlements near the Pacific Coast. On reaching the summit of

Panamint Mountain they took one look back at the valley and a member of the party exclaimed, "Good-bye, Death Valley," which name has been retained ever since. To those interested in reading a true and thrilling story of these early pioneers, I commend Manley's book. Little did those adventurous pioneers know of the mineral wealth in that land of desolation in which they all so nearly perished. While the surrounding mountains have yielded much wealth in gold, silver, lead, copper and other metals, its greatest riches were found later in the vast deposits of borate minerals.

ULEXITE,—is usually found in loose-textured masses, made up of fibers, or capillary crystals. It is a hydrous sodium calcium borate and was the first borate mined in Death Valley. It was also being recovered from Rhodes Marsh in western Nevada. On the floor of Death Valley, in the salt crusts and in the mud strata below, it occurs in fibrous silky-like balls called "cotton balls." It is also quite commonly found in more compact fibrous masses in the hills bordering the western side of Furnace Creek.

COLEMANITE — In the year 1882 the mineral colemanite, a hydrous calcium borate, was first found by William T. Coleman, and which from the time of discovery until about 1935 was the source of over 50% of the world's supply of borax. About 1935 the mining of colemanite was practically discontinued and operations transferred to Kramer District, Kern County, where immense deposits of kernite and borax had then been discovered.

Colemanite is frequently found in colorless, brilliant, monoclinic crystals, some of these short and prismatic, some rich in forms, others in brilliant drusy masses or, more rarely, in crystals that resemble acute rhombohedrons. This latter habit was found in unusually large crystals in the lower Blanco Hills (Mt. Blanco) in Furnace Creek Wash, some exceeding 1½ inches in length. The other crystals of more common habit found in upper Furnace Creek Wash have attained the largest size found, some measuring over three inches across the base where they are attached to the wall of the cavity in which they occurred. Many of these large crystals are quite transparent and brilliant; they are perhaps the largest ever found. Down in lower Gower Gulch doubly terminated crystals are found, in length from ½ to over 2½ inches.

The colemanite deposits in the Death Valley region, which are confined mostly to the Blanco Hills and the Ryan district, are found in great beds interstratified with lake deposits of Tertiary age. In places these deposits are associated with large amounts of gypsum and average from a few inches upto fifty feet thick. These beds of colemanite extend over an area of some miles, although somewhat discontinuous and irregularly distributed. The tonnage of good ore still untouched would reach a staggering figure, even after some fifty or sixty years of exploitation. Outside of one locality in Esmeralda County, Nevada, colemanite is found only in California. It has not been reported from any other country to the writer's knowledge.

PRICEITE, — a hydrous calcium borate, is abundantly distributed in the area where colemanite occurs. It is found in white, massive, porcelain-like pieces as float in the washes or in somewhat decomposed volcanics in lenses or irregular veins rarely over four or five inches in thickness. It is rarely found somewhat translucent, but mostly is dense and quite opaque. Priceite was also mined near Brookings, Curry County, Oregon, in the 70's and a considerable tonnage shipped to England. Mining ceased there many years ago.

MEYERHOFFERITE, — anothed hydrous calcium borate, occurs in prismatic, triclinic crystals, often in reticulated masses, and is found in only three or four places in the Blanco hills. It was first found in considerable amount in what has become known as Meyerhofferite Tunnel near the head of Twenty Mule Canyon, and a'so in a smaller occurrence near the mouth of Schaller Canyon about

two hundred yards farther south. These long prismatic reticulated crystals are usually in a matrix of pure white, compact, fibrous meyerhofferite which has resulted from the alteration of inyoite. Some years ago large groups of beautiful snow-white monoclinic crystals were found in a large cavity in Meyerhofferite Tunnel. These crystals are pseudomorphs after inyoite and most of them are one-half to one inch across, the largest being over two inches. It was the writer's good fortune, with the aid of a friend, to find this large cavity, about six feet in length and extending horizontally a distance of about four feet into the wall of the tunnel. The entire surface of the ceiling was grown over with large and small, perfect crystals of the meyerhofferite pseudomorphs, the whole surface of the purest white, and a thing of exquisite beauty long to be remembered.

A mile or two down Gower Gulch a rather unusual occurrence of Meyerhofferite was found in somewhat nodular forms mixed with more or less clay in a fissure in colemanite. These nodules, when broken open, exhibited a finely radiated structure, and on the outside of some nodules quite good crystal terminations could be seen when the clay was removed. Most of the smaller nodules varied in size from three to four inches in diameter, but large pieces up to eight inches thick were collected, and these were made up mostly of small, rounded nodules all showing beautiful glassy crystals radiating from the center.

INYOITE, — a very rare borate of calcium, occurs in the meyerhofferite pseudomorphs after inyoite in glassy, small, narrow pieces which are remnants from the original unaltered inyoite. It was identified and described by Schaller, (2) along with meyerhofferite.

Thin plates made up of minute colemanite crystals, forming casts of large monoclinic crystals of inyoite, were found in two different places in the Mt. Blanco district.

PROBERTITE — is a hydrous sodium calcium borate commonly found in radial glassy aggregates in clay with colemanite and ulexite. It was found near Ryan in the Widow and upper Biddy McCarthy Mines and also two years ago in Schaller Canyon. Its occurrence in the Death Valley region seems to be limited to these two localities.

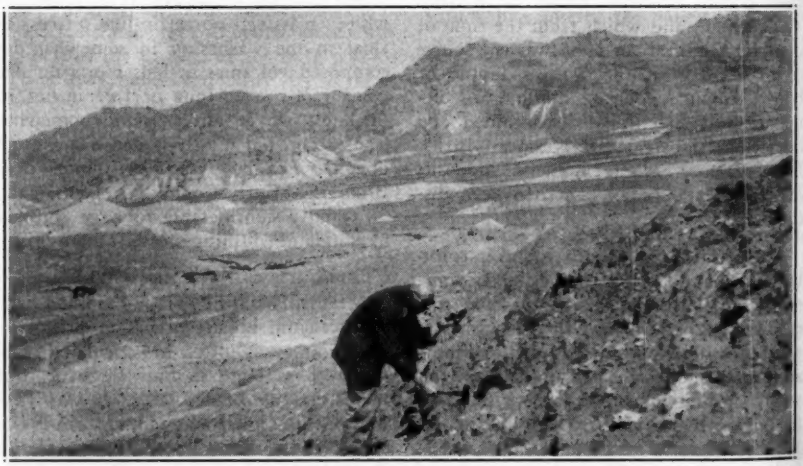

Fig. 2

Dr. Waldemar Schaller collecting borates on Gyp Hill.

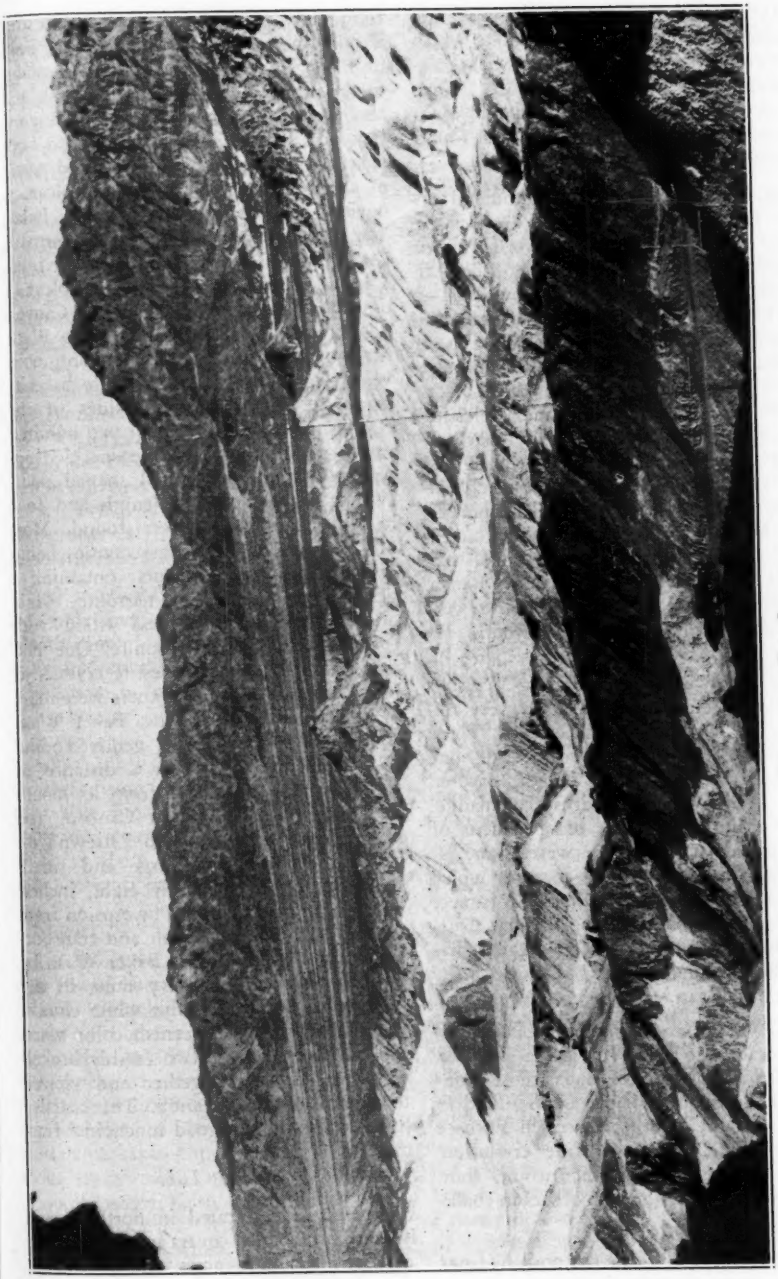

Fig. 3
View across Furnace Creek Wash looking east across part of Death Valley.

HYDROBORACITE — is a very rare hydrous calcium magnesium borate which occurs in needle-like crystals with colemanite. The exact locality at Mt. Blanco is not known and, even though energetically searched for, has not been found in recent years.

BORAX — is a common mineral on the floor of Death Valley, associated with the large salt beds covering more than fifty miles of the valley floor. It is also found in small shallow pits at the Gnomes Workshop about a mile and a half north of Furnace Creek Ranch.

Much gypsum is found in the Furnace Creek area associated with the borates in the hills on the west side. Celestite, a sulphate of strontium, is sparingly associated with the borates throughout the region. Fine orthorhombic crystals up to an inch in length, well terminated and brilliant, were found with colemanite at the Coleman Claim about two miles north of Furnace Creek Ranch. Small brilliant crystals of celestite were also found in Corkscrew Canyon.

In one or two cavities, also in Corkscrew Canyon, meyerhofferite crystals have been entirely replaced by very minute, brilliant, colemanite crystals. These replaced crystals of meyerhofferite, one to three centimeters in length, covered most of the surface of drusy colemanite. Only a limited number of specimens of this particular occurrence were found. It has been called shredded coconut, which it does somewhat resemble, and is very striking on account of its brilliancy. Colemanite pseudomorphic after inyoite, has also been found in the Biddy McCarthy Mine near Ryan. (3).

HOWLITE, — a hydrous calcium silico-borate, is found in white compact nodules in many places, but is most abundant in lower Mt. Blanco; it is found in lesser amount in other places in Furnace Creek Wash. It has a fine crystalline structure consisting of microscopic, thin, flattened crystals, and also occurs in chalk-like earthy masses.

BAKERITE, — the second hydrous calcium boro-silicate to be discovered, was found in place in the Furnace Creek area at only one locality, that being at the head of Baker Canyon in the Black Mountains to the west of Furnace Creek Wash and about a mile or two south of Corkscrew Canyon. Baker Canyon, flanked on both sides by steep mountain bluffs and partly of clay but consisting mostly of volcanics, opens into a large wash known as Baker Wash, which is seperated from Furnace Creek by a low ridge of dry mud hills. The bakerite occurs in altered volcanics on both sides of upper Baker Canyon near its abrupt termination in the Black Mountain Range. Irregular discontinuous veins, lenses, and pods of white bakerite mark the bluffs on both sides of the canyon for a width of about two hundred yards, giving them a white speckled appearance. Some large oval shaped pods, five to eight inches in length and four to six inches thick, were found. Most of them are hollow, some cavities being divided into compartments containing a great many needles of natrolite, while others were more or less filled with coarser crystals of thomsonite. One pod was found to contain celestite crystals of pale blue color, and still others were more or less filled with selenite. Baker Wash consists of a broad plain gently sloping to the northwest, and at a distance of about a mile and a half from its mouth intersects lower Corkscrew Canyon. The entire length of Baker Wash is strewn with bakerite in fragments large and small, some up to six, or rarely eight, inches, which have been removed by erosion from the head of Baker Canyon and transported down its length into Baker Wash by run-off water from heavy rains in the mountains. Some are solid white chunks which show a pale greenish color when broken open and the two freshly broken ends placed close together and viewed through the thin opening. The massive bakerite has quite a good conchoidal fracture.

Searles Lake

Searles Lake, located in northern San Bernardino County, covers an area of seven or eight thousand acres and is truly a remarkable body of salts. It differs from

the ordinary playa common to the desert which usually dry up entirely during summer months. The greater portion of Searles Lake consists of a solid body of salts, mainly halite. No attempt will be made here to describe the many interesting minerals of the lake except to mention the two borates found there. Suffice it to say that it is rich in remarkably fine crystallized specimens. Most of these minerals have been described by W. F. Foshag in various papers of the U.S. National Museum at Washington, D. C.

Borax crystals, perfectly developed and of varied habits, are found in great numbers associated with the many other interesting minerals in Searles Lake. Perhaps the finest crystals of borax in collections here in the west came from this lake. On account of their high water content they are somewhat difficult to preserve, but with proper care many are kept in a fine state of preservation.

TINCALCONITE, — a sodium borate with only five molecules of water, was recently found on the lake in pseudo-octahedral crystals from one-half to two millimeters in size. While the crystals do resemble octahedrons, they belong to the hexagonal-rhombohedral system. They are of very rare occurrence and were described by Pabst (4). The American Potash & Chemical Company recovers several hundred tons of borax daily from the brine in their potash operations on the lake.

Kramer Borate District, Kern County

The discovery of borates in the Kramer district and later development work there is said to make it the most important source of borax and borate minerals in the world, (5) Production of crude borate minerals from 1926 to 1946 was approximately 2,000,000 tons, with an average content of 40% boric acid. This most remarkable borate district is located about thirty miles southeast of Mojave in southeastern Kern County. Discovery was first made by Dr. Olevio Suchow in the fall of 1913 while drilling a well for water on a forty acre homestead claim. At a depth of 340 ft. colemanite was found, and later ulexite. For a period of about twelve years exploratory work did not prove very encouraging but in 1925 a drill hole penetrated the great tabular body of sodium borates composed of kernite and borax. In August, 1926, this new type of borate deposit was reached by mine shaft.

As to the size of the Kramer borate deposits, Gale (5) says, "As developed by drilling and mining the borate deposit lies within an irregularly oval area about four miles in length from east to west and one mile in width from north to south. This area was approximately an oval basin of deposition during the epoch in which the borates accumulated and has been moderately deformed since that time so that the beds lie in a synclinal basin now depressed to a depth of one thousand feet and more along its axis. The present borate deposits range in depth from about three hundred feet to one thousand feet below the surface of the ground." The borate deposits at Kramer, like those in other places in California, occur where late Tertiary volcanism is apparent.

Since the Pacific Coast Borax Co. began extensive mining on this deposit in 1926, the immense tonnage of ore taken out has consisted almost entirely of kernite and borax. Production from this area will continue for many years, as it is estimated that a million tons of ore are still in reserve.

KERNITE, — locally called rasorite, is a sodium borate containing four molecules of water and is a new borate mineral which was described by Schaller (6). It occurs with borax in great beds; the crystals are monoclinic and often of great size, some eight feet in thickness. Kernite has two perfect cleavages and is glassy clear when pure. The native borax here forms massive beds of crystalline sodium borate and is often called tincal. Borax also occurs as a secondary mineral from the alteration of kernite in quite large masses, but not as a pseudomorph. Borax and kernite compose the major borates of the Kramer district. Very fine pseudomorphs of ulexite after borax crystals were found several years ago with all crystal forms perfectly preserved.

PROBERTITE, — also called kramerite a hydrous borate of sodium and calcium, occurs quite abundantly in places in the mine. It is usually found in the kernite or in the clay or sediments, and usually forms spherulites which show radiating glassy crystals. Rarely, it occurs in prismatic single crystals or in groups of prisms. It is monoclinic and has a perfect cleavage.

ULEXITE — is a common mineral in the district and occurs in compact fibrous veins in the clay that overlies the kernite and borax. It has a very striking appearance due to its rich silky luster. It is also found rarely in flattened masses resembling lily pads one to five inches across.

COLEMANITE — occurs sometimes embedded in the ulexite, and the writer has a large chunk of compact ulexite with fair colemanite crystals scattered over its surface. Where it is found enclosed in ulexite it appears to have been derived from alteration of the ulexite. It is also found in nodules in clay or as prismatic crystals in geodes.

HOWLITE, — has been found in only one place in the Kramer district. Gale reports it in one or more thin nodular lenses in the footwall of the 950 ft. level of the Western Borax Mine.

TINCALCONITE, — is found as a white powder on kernite and borax. It is a common mineral on the desert where borates are found and results from dehydration of borax.

INDERITE, — a very rare magnesium borate, was recently found in the district in a drill core; only several small pieces were collected and no more have since been found. This is no doubt the only occurrence reported in the United States.

REALGAR, — occurs at several places in the mine as inclusions in the borax and kernite, giving it rather an attractive reddish brown color. A little stibnite is also found there and a mineral first thought to be kermesite but later shown to be another species was found two or three years ago.

The mineral, szaibelyite, which is a hydrous magnesium borate, is found near Stinson Beach, Marin County. It occurs in the serpentine rocks there as impregnations filling small cracks and fissures in the rock. It was originally called camsellite but later investigation has proven it to be identical with szaibelyte, which name now prevails.

At the Gerstley Mine, about five miles northeast of Shoshone, Inyo County, California, a large deposit of colemanite has been worked for many years. Much satin spar-like ulexite in veins of quite striking silky luster occurs along with the colemanite. An occurrence of colemanite, although a small one, was reported found east of Salton Sea, San Bernardino County.

Colemanite was found in several other places on the desert, notably at Borate, nine miles east of Yermo, San Bernardino County, where it was mined on a large scale years ago. Geodes lined with beautiful large crystals were common. Beautiful, well terminated crystals of celestite were sometimes found in the geodes. These celestite crystals are quite remarkable for perfection of form.

A vein of colemanite about six inches in width, reported as associated with strontianite on the "Gem Placer" claim about five miles southeast of Daggett, San Bernardino County. Only a very small production of colemanite was reported from this mine. It is a somewhat interesting occurrence, since it is perhaps the only colemanite reported as occurring in strontianite.

At Lang, Los Angeles County, the rare and new mineral, veatchite, a borate of strontium, was discovered by Wm. Nisson of Petaluma, California. This mineral was described by Switzer (7). It was originally considered a calcium borate, but later found to be a borate of strontium. It is monoclinic and occurs in white cross-fiber veins in limestone and in howlite. Colemanite was mined at Lang for many years. Ulexite and howlite are associated with the colemanite in considerable abundance.

In Ventura County in the Fraser Mountains a colemanite deposit, somewhat like

that of Lang, was described by Gale. A considerable tonnage of colemanite was mined there for some years.

The described borate districts have all proven interesting localities for mineral collectors. Of course, Borax Lake, presents some rather serious problems in collecting its minerals. Only in those rare years when the lake has practically dried up, is it possible to get any minerals. The Death Valley region covers a large area and much good material can still be found there if energetically looked for.

The Kramer district is very interesting but, on account of its limited number of minerals and the difficulty of getting underground and finding the specimens, it is less prolific in fine minerals than some of the other districts. Borate, in the Calico district, San Bernardino County has been a very interesting locality because of the very fine crystallized specimens found there, particularly colemanite and celestite. Lang has no doubt produced nice specimens in its day, but the writer did not visit the mine nor go underground until about the time it was abandoned. However, it is believed that the finest howlite occurs there, and the only occurrence of veatchite is at Lang.

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"THE GEYSERS," SONOMA COUNTY, CALIFORNIA

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Introduction

Situated in the heart of the Coast Ranges, in Sonoma County, California, is a small health resort known as "The Geysers." The resort buildings, the oldest of which is said to date from 1852, are located along Big Sulphur Creek, across from a very intense area of thermal activity. The resort is widely known because of the curative powers of its mineral waters and baths. It is visited by comparatively few people, however, because of its rather remote location. The name "The Geysers" is a misnomer, for the thermal activity is all in the form of hot springs,fumaroles, and artifically developed steam wells; no true geysers exist in the area.

"The Geysers" lie about 90 miles north of San Francisco, and may be reached by a good paved road which turns east from the Redwood Highway (U.S. 101), about one mile north of Healdburg. Another road leads to "The Geysers" from Cloverdale, but it is neither as good nor as scenic.

As part of a continuing research program being carried out on the saline minerals, the writer spent part of the summer of 1949 at "The Geysers," studying the thermal activity and collecting samples of the salts that crystallize around the fumaroles and hot springs.

I thought it a rather remarkable coincidence when, upon inquiring into the early history of the area from its present owners, I learned that it was discovered in the year 1850 by a Mr. Elliot, while tracking down a wounded bear, and that Mr. Elliot was my uncle's grandfather.

General Geology

"The Geysers" is situated in the midst of a vast complex of igneous sedimentary and metamorphic rocks known as the Franciscan Formation, probably of upper Jurassic age. In the immediate vicinity of the area of thermal activity the exposed rocks consist of slightly metamorphosed volcanics and sediments, plus intrusive bodies of serpentine and their associated glaucophane schists.

Evidences of late Tertiary volcanic activity are revealed by the presence of lava, chiefly andesite, exposed on the summits of nearby Mt. Cobb, Mt. St. Helena, and other high peaks.

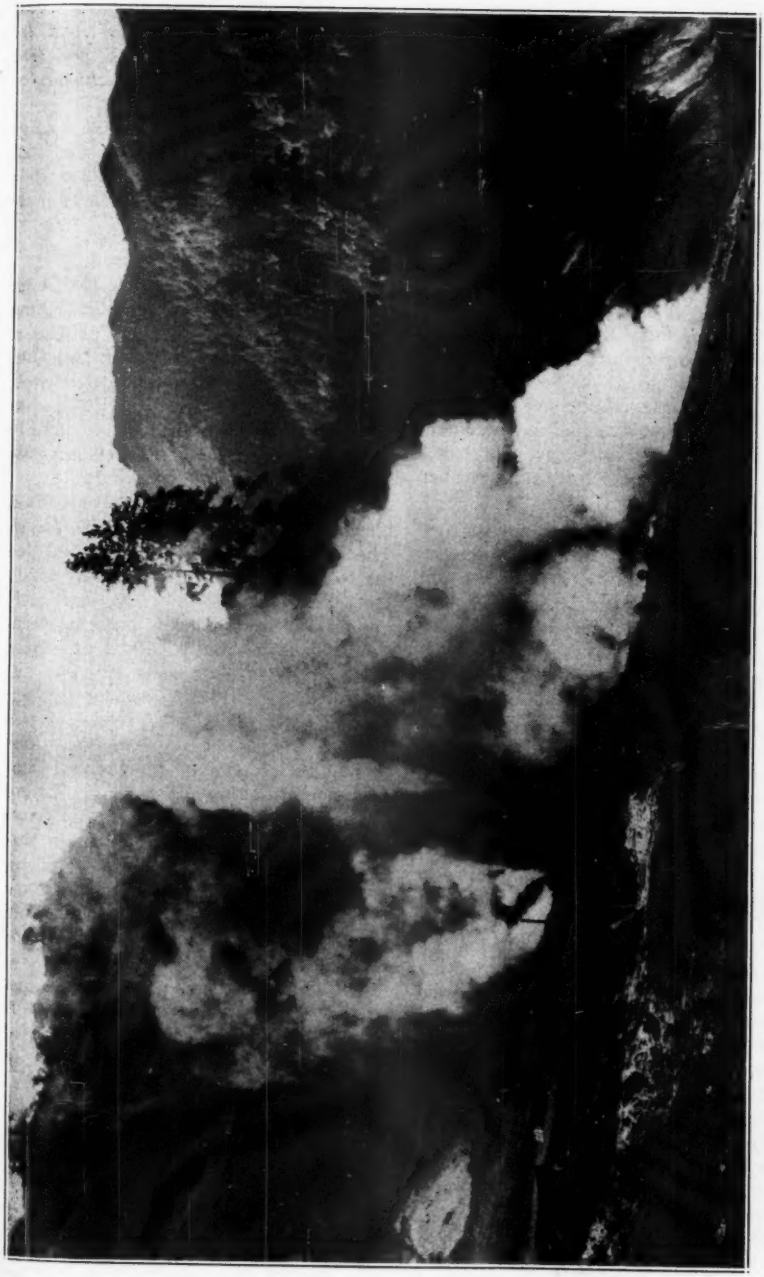
In addition to "The Geysers" there are other hot springs in the vicinity as well as numerous quicksilver mines, all of which are associated with warm, hot or sulfur springs. The hot springs and quicksilver mines are related to faulting, as shown by their alignment along a nearby straight east- west trending fault. One such alignment includes the Little Geysers, five miles east of the Geysers, The Geysers, Sulphur Bank, one mile west, and finally the Cloverdale Quicksilver Mine, an area of declining fumarolic activity, 20 miles farther west.

There appears to be little doubt that both the hot springs and quicksilver mines in this area have a very close genetic relation to a period of late Tertiary volcanic activity.

Hot Springs and Fumaroles

The principle area of thermal activity at "The Geysers" is along Geyser Creek, a minor tributary of Big Sulphur Creek, which joins Big Sulphur Creek across from the resort buildings. Beginning at Big Sulphur Creek, where several hot springs are found, the hot ground extends east-west for a distance of about 400 yards, and stretches up the steep slope along and on either side of Geyser Creek for distances varying from 200 to 500 yards, a total area of about 35 acres. The boundaries of the hot ground are sharply defined, for it is almost devoid of vegetation.

From a distance on a hot day at noon the area looks little different from the surrounding country. Early on a cool



Early morning view of one of the fumarole areas east of Geyser Creek Canyon, "The Geysers," Sonoma County, California.

morning, however, the principal area of activity, Geyser Creek Canyon, is filled with a huge cloud of steam, while the steam wells send dense white plumes high into the air.

A walk along the trail up Geyser Creek soon brings one to a fascinating area of intense thermal activity. Boiling hot springs are everywhere, and the very ground under one's feet in places is simmering with boiling water and steam, so that there are short stretches along the trail where it is much too hot to stand in one place for more than a few seconds. The normal air temperature during July and August in these deep Coast Range valleys commonly rises above the 100° mark. Thus Geyser Canyon may become a veritable inferno on a hot day. The strong odor of hydrogen sulfide adds further reality to this allusion.

In addition to the boiling hot springs, there are numerous steam jets along the canyon walls, the orifices of which are commonly lined with beautiful bright yellow needles of sulfur, but so fragile and delicate as to almost defy collection. In other places are areas where the steam just "oozes" forth from hot, soft, highly decomposed rock. The Smokestack, near the head of Geyser Creek and just to the west of the Devil's Pulpit, is the largest fumarole, and pours forth the largest volume of steam.

Collecting samples of the salts that encrust the ground near the hot springs and fumaroles can be hazardous. On hot days, when the steam is invisible, I had the frequent experience of sticking my hand into a jet of live steam, and on other occasions very inopportunely stood so that a jet of steam shot up my pants leg. The ground everywhere is saturated with a rather strong solution of sulfuric acid, which can completely ruin the clothing of the mineral collector, who, unlike the average sightseer, will soon be lying prone in various out of the way places trying to reach an especially attractive looking specimen.

Temperature measurements of the hot springs showed them to range from just slightly warm to a maximum equal to boiling water at that altitude, about 97.5°C. The temperture of any particular spring will vary somewhat with the season of the year due to varying amounts of dilution with rain water.

Acidity measurements showed a range from just about neutral in the cool springs, to rather strongly acid, with a pH of 2.5. No alkaline springs were found.

Steam Wells

In the summer of 1921 J. D. Grant, of Healdsburg, California, began drilling on the hillside to the east of Geyser Creek with the hope of utilizing the steam for power. He did a remarkable job, considering the unusual difficulties involved, and it was probably due more to luck than skill that no one was seriously injured during this undertaking.

The first shallow hole, when closed, blew out the casing and was abandoned. The well designated as No. 1 was drilled the following summer to a depth of 203 feet. For the first 80 feet, only soft ground was encountered, but the steam flow increased rapidly with depth. At a depth of 80 feet, sandstone was encountered, and drilling continued through it, after which an 8-inch steel casing was lowered and anchored in the sandstone by pouring around the pipe several hundred pounds of molten zinc. The casing was then capped with a heavy gate valve. Ordinary churn drilling equipment was used in drilling the first wells while rotary drilling equipment was used on some of the later holes. The steam in the hole was controlled by admitting a stream of cold water to condense it.

Encouraged by the success of the first well, a series of seven additional wells were drilled, the last one being completed in 1926. No further drilling has been done since that time. These wells produced powerful sources of steam, with pressures ranging from 64 to 276 pounds per square inch, and temperatures from 122 to 190°C. The only use that has been made of this power has been to drive a small generator which supplies electricity for the Geysers resort.

In the 23 years that had elapsed be-

Steam Well No. 4, "The Geysers," Sonoma County, California. The roar made by this high pressure steam column may be heard for miles.

tween the time the last of the wells was drilled and my observations were made in 1949, some of the wells had caved in. However, five are still in fairly good condition, some capped and some open. The wells are emitting steam with a fearsome roar that can be heard for miles as the area is approached by road. The noise of the steam rushing out through the ten inch steel casings is completely deafening at close range. Even by placing one's lips at the ear of a companion, and shouting at the top of one's voice, communication is impossible. Well No. 7, "Whistling Hanna," is especially noisy because the high pressure steam is issuing from a small orifice. Working at close proximity to one of these wells for an hour or two renders one partially deaf for several hours later.

Because of the present corroded condition of the casings and valves it was impossible to repeat the pressure measurements made in 1925 by Allan and Day. However, judging from the noise and velocity of the steam, there has been no appreciable cessation of intensity in the nearly 30 years since the first well was drilled, even in those that are not capped. Neither has the opening of the wells had any visible effect on the intensity of the fumaroles.

By means of a maximum thermometer attached to a stick it was possible to make temperature measurements of the open wells, but only at a depth of about two feet below the mouth of the casing, The maximum temperature measured was 136°C, which is much lower than it would be at greater depth, or in a capped well, This, too, indicates that there has been no appreciable decrease in activity since the wells were first drilled.

Mineralogy

A complex suite of minerals, mostly sulfates, are constantly forming about the various hot springs and fumaroles. Mineral collecting here is seasonal, since the salts, most of which are water soluble, are largely washed away during the rainy season, which usually lasts from October to April. The best time for collecting is early summer, especially after a dry winter, when a new crop has accumulated. However, at any time of the year good specimens of many minerals may be collected by working in protected places, such as under overhanging rocks.

Many of the salts are highly deliquescent or efflorescent, and if they are to be preserved must be tightly sealed in jars at the time they are collected. Mason jars, of the type used in home-canning of fruits and vegetables, were found to be satisfactory for this purpose.

A brief description of the sulfates from "The Geysers" has been published by M. Vonsen. Studies are still in progress on the materials collected by the writer.

A list of the minerals so far identified is given below. In addition, several unidentified ones have been found, some of which appear to be new species.

The most common salts present are sulfates of pottassium, aluminum, ammonium, magesium, calcium and iron. In this "nature laboratory" there is no reason why numerous other combinations of these elements should not be found from time to time.

Minerals at "The Geysers"

Alunite	$K\ AL_3(OH)_6(SO_4)\ 2$
Alunogen	$AL_2(SO_4)_3.16H_2O$
Boussingaultite	$(NH_4)2Mg(SO_4)2.6H_2O$
Epsomite	$MgSO_4.7H_2O$
Gypsum	$CaSO_4.2H_2O$
Halotrichite	$FeAL_2(SO_4)_4.22H_2O$
Mascagnite	$(NH_4)_2SO_4$
Melanterite	$FeSO_4.7H_2O$
Sulfur	S
Tschermigite	$(NH_4)AL(SO_4)_2.12H_2O$
Voltaite	$K_2Fe_5Fe_4(SO_4)_{12}.18H_2O$

Origin of the Steam

The question that first comes to mind as one walks along the trail leading through the hot ground is, where is all of the energy coming from? It seems quite obvious that somewhere at depth there must be a great "furnace" which is giving off large quantities of heat, and undoubtedly has been doing so for untold thousands of years.

Areas of hot spring and fumarole activity are common around volcanoes such as Mt. Lassen, or in areas of known recent volcanic activity, such as the Yellowstone Geyser Basin. Here the evidence is clear that the hot springs and fumaroles are caused by bodies of molten rock, or lava, which have been pushed up to the surface from unknown depths below. At "The Geysers" there are no volcanic rocks exposed at the surface, only the old Franciscan rocks, which certainly have no bearing on the origin of the thermal activity. However, the fact that there are evidences of fairly recent volcanic activity only a few miles away, makes it almost certain that the heat at "The Geysers" is supplied by a body of hot rock at depth, which for some reason was never able to force its way to the surface. Instead, it has been slowly giving off its heat through cracks and fissures in the overlying rocks which connect it with the surface.

There are two types of water which might furnish the steam now issuing from the fumaroles and steam wells. The first of these is *meteoric water,* that is water that descends from the heavens in the form of rain. The second is *magmatic water,* or water that is given off within the earth's crust from a molten rock, or magma. There are three possible explanations for the steam at The Geysers: (1) it might be magmatic, (2) it might have been generated by the heating of surface water that has seeped downward until it is in contact with the underlying hot body of rock, or (3) it might be a mixture of both.

The latter hypothesis is probably the correct one. It has been well established that magmas do not contain large quantities of water, not more than a few percent at the most. Therefore, even a large magma chamber could not give off the quantity of water that has passed into the atmosphere as steam, or run off as discharge from the hot springs, in the untold number of years that this area has been active. Undoubtedly part of the water stems from the hot body of rock beneath, but the major portion of it must be reactivated surface water.

The mineral matter carried upward by the steam and hot water, likewise, must come in part from emanations from the underlying hot rock, and in part by partial solution of the overlying Franciscan rocks by the steam.

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BROOKITE CRYSTALS FROM FRANKLIN, N. J.

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The great variety of minerals which have been found in and near Franklin, N. J., never ceases to amaze the mineralogist. These notes add still another species to the long list of nearly 150 minerals which have been reported.

This polymorph of TiO_2 was found in a boulder of dolomite on the dump of the Buckwheat mine, a spot which has been a favorite with nocturnal scavengers equipped with ultraviolet lamps. From time to time, the dumps have been reworked for what was once lean ore, limestone with grains of willemite, franklinite, and occasionally zincite. More plentiful, however, are masses of gneiss, and of camptonite. Not uncommon are narrow dikes of camptonite in limestone.

Palache (1) has described the occurrence of dolomite veins at Franklin as follows: "The only well-defined occurrence of dolomite was in the Buckwheat mine at Franklin, where the stripping exposed a zone of gray dolomitic limestone, fine granular to compact and porous in places; which cut across the white limestone between the two legs of the ore body. Some cavities, several inches across, were lined with drusy rhombohedral crystals of white pearly dolomite. In the cavities and of later formation were calcite, quartz, albite, sphalerite, pyrite, millerite, hematite, and goethite, mostly well crystallized."

A mass of this porous dolomitic limestone, recovered from the dump of the Buckwheat Mine, was broken up into small fragments for examination under a binocular microscope. Many fine crystals of a number of minerals were found, including crystals of brookite, a mineral so far reported from only one other New Jersey locality. This was in some quarries near Princeton, where Hawkins (2) described brookite in 1913 as small transparent crystals found in joints in Triassic sandstones and shales near trap rock, and associated with ilmenite, barite, and analcite.

The brookite occurred sparingly as small, lustrous, coal-black crystals, rarely more than 2 mm. in length. These are remarkable for their habit of elongation in the direction of the a axis,—a new habit. Since the identification of the mineral is based upon measurement of crystal angles, the angles of several pyramidal faces are tabulated below. No new forms were found.

Table 1. Angles of Brookite, Franklin, N. J.

Form	Average of	Measured		Goldschmidt	
		phi	rho	phi	rho
o (111)	4	49°52'	55°45'	49°55'	55°43'
s (322)	4	60 44	62 29	60 42	62 36
e (122)	4	30 42	47 46	30 43	47 41

The dolomitic limestone is grayish, and granular, with tiny vugs in which the following minerals were found.

Dolomite: Colorless rhombohedra projecting from the walls, and sometimes coated with a pearly micaceous mineral.

Sphalerite: Resinous brown, translucent twinned tetrahedra, combined to form sharp octahedral crystals; but sometimes these are quite rounded or even globular.

Pyrite: Pyritohedra, with tarnished surfaces, usually embedded in the dolomitic limestone. In cavities, these crystals have been reduced to reticular aggregates of elongated (acicular) cubes, through some obscure secondary process.

Calcite: Scalenohedral crystals modified by rhombohedra. The scalenohedral faces are apt to be pitted.

Albite: Very abundant in exquisite water-clear twinned crystals.

Orthoclase: Subparallel growths of pinkish crystals.

Calamine: A few microscopic druses were found.

Millerite: Rarely in hairy wisps.

Quartz: Small, limpid prismatic crystals, with prism faces sometimes smooth and free of striations.

Apatite: Rarely in colorless, minute elongated prisms.

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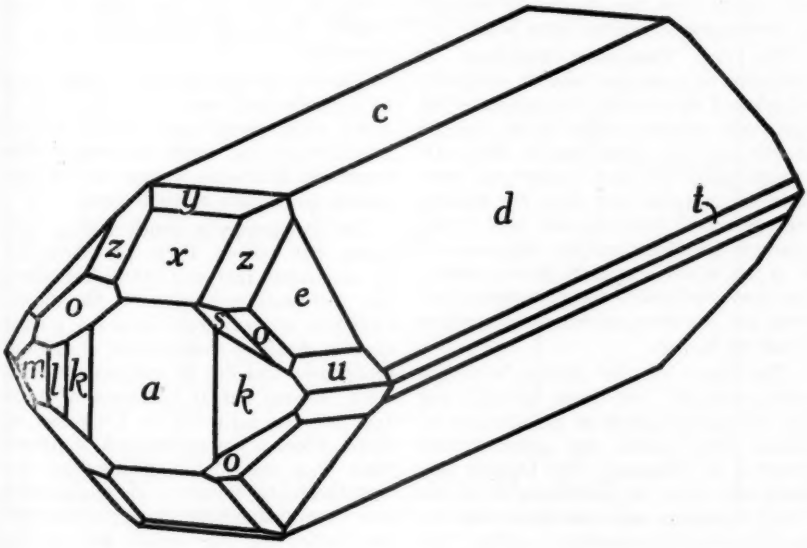


Fig. 1

Brookite, Buckwheat Mine, Franklin, N. J. Forms: c (001), a (100), m (110), l (210), k (410), y (104), x (102), d (043), t (021), o (111), z (112), e (122), s (322), u (121).

THE RIBAUE — ALTO LIGONHA PEGMATITE DISTRICT, PORTUGUESE EAST AFRICA

MARK C. BANDY

Economic geologist (Ph.D.); mining engineer (tin mining at Llallagua, Bolivia); amateur mineral collector.

The writer had the privilege of visiting the Ribaue-Alto Ligonha district for several days in October, 1949, during the course of a survey of mining districts in Portuguese East Africa. In view of the wide variety of minerals and the superb quality of some of the crystals found there a brief description of the district and some of the minerals may prove of interest.

It is not impossible that the ancient and unknown people who worked the Southern Rhodesian and Mozambique gold deposits may have obtained some gold from this area. Certainly their caravan routes from the interior to the port of Sofala passed not far from here.

The first Portuguese settlement in northern Mozambique was at Angoche, established about 1650. It is probable that these early settlers searched in the Ligonha district for gold from time to time. Although gold has been known to occur here for centuries and mica for decades the district is little known outside the territory and there are few references to it in the world literature. Active mining has been confined to the past twenty-five years and has been carried on in a rather desultory fashion.

The center of the district is at approximately 15° 30' south latitude and 38° 15' east longitude in the Province of Niassa. The capital and administrative center is at Nampula. The District formerly was under the administration of the Nyasa Company and was taken over by the Provincial Government in 1929. The pegmatite area has a triangular shape and is approximately 70 miles north-south and 40 miles east-west along the southern base.

Access is by the Lumbo-Malema railroad from the port of Lumbo to Ribaue. There is also a good road more or less parallel to the railroad. To reach the southern half of the area one must make a wide detour to the west through the administrative posts of Alto Molocue and Alto Ligonha. It is approximately 170 miles from the coast to Ribaue and another 70 miles to the southern part of the district.

The climate is hot but not unpleasant. The average temperature is approximately 75 degrees with a mean minimum of approximately 64 degrees and a mean maximum of 85 degrees. The rainy season is from December to March with about 30 inches of rain. The dry season is from May to September with light rains in November.

There is an open growth of forest over most of the area with a variety of hardwood trees, ebony and African sandalwood being the most interesting. The vegetation along the streams is lush and consists principally of spear grass.

The topography is gently rolling with rather flat valleys. There are a number of mountains that rise 3000 feet above the surrounding country in the north. One sees an occasional rounded granite knob or dwala so characteristic of African topography and due to spheroidal weathering. Ribaue has an elevation of 1200 feet and the hills rise to 1500 feet or more. About seven miles south of Ribaue there is a low divide. Throughout the area there are numerous sluggish creeks and rivers that greatly impede transportation during the rainy season and are dry during the dry season.

The area is comparatively heavily populated, the native inhabitants belonging to various tribes of Bantu stock. They are ingenious and, in general, good workmen who learn readily to handpick ore. Although agriculture is the principal source

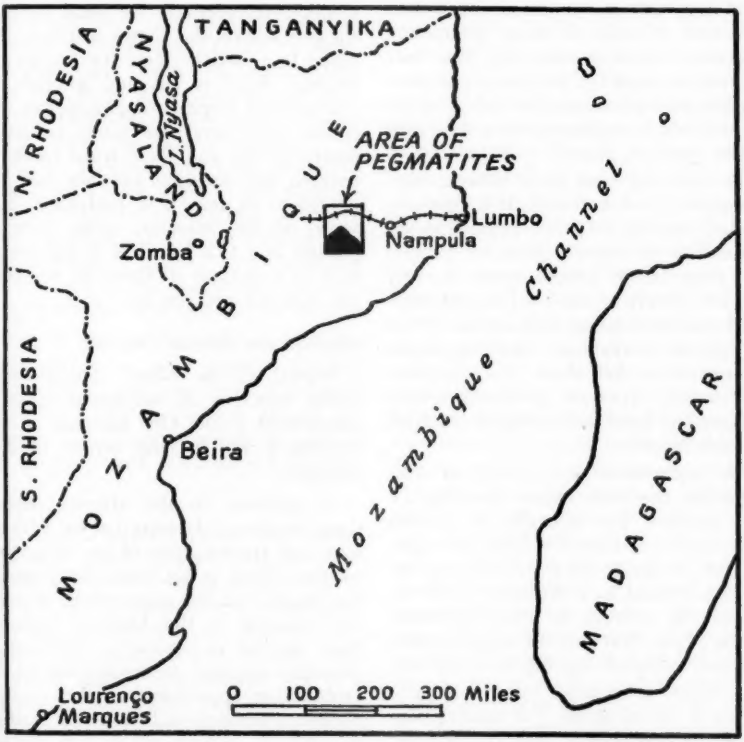
of livelihood, many of the natives have worked in the Rand gold mines and are experienced miners.

Geology

There has been no adequate geologic study made of the area. The only publication known to the writer is by Borges and Nunez (1). This is in Portuguese and gives no information about the pegmatites.

The district lies on the central plateau area of Mozambique. This is an area of Archean schists and gneisses that have been intruded by pre-Cambrian granite. There are a few intrusives of younger (?) basic rocks now generally altered to serpentine. To the south and west the basement complex passes under sedimentary beds of the Karroo System.

Erosion since pre-Cambrian times has reduced the area of metamorphics to ir-



Map of eastern Africa showing location of the Ribaue-Alto Ligonha pegmatite district. The area of pegmatite mines is in solid black.

regular and relatively thin and narrow roof pendants in the granite. The bedrock is covered by lateritic soil and outcrops are not common.

The pegmatites occur, as a rule, in the metamorphics, usually in the schists. There can be little question but that they have been formed by emanations from the granite. There is no regular pattern of strike or dip nor relationship to the granite contacts. Due to the vegetation and lateritic soil the only pegmatites known to date are those with quartz cores that outcropped or those containing relatively large amounts of mica with a shallow cover of soil. So many pegmatites have been found in this way that there has been no need for systematic prospecting. Should modern geophysical prospecting methods be employed many new pegmatites could be found.

No study has been made between type of pegmatite and wall rock. It is generally believed that the mica-rich pegmatites are confined to the schists. Since the pegmatites range from simple types to very complex a study of the field relationships could yield interesting data on this phase of pegmatite formation. There appear to be pegmatites that show all gradations from simple types to essentially quartz veins on one hand and to highly complex types on the other.

The pegmatites vary greatly in size. In general, the more simple the type, the more uniform the lenticular or tabular shape; and the more complex the type, the more irregular the form. Mining has not been carried to a sufficient depth to indicate the average or even minimum vertical extent. Some of the large deposits have been prospected to depths of 60 feet.

As might be expected there is no uniformity of dip or strike. The smaller pegmatites are, in general, vertical while the larger ones may have one wall with a flat dip.

In the simple types zoning appears to be quite regular with beryl occurring along the feldspar—quartz core contact and minerals such as tantalite in the mica border zone. In the more complex types zoning was not apparent.

Mining

All the pegmatites have been worked by open cuts and quarries. There are a few short drifts and exploratory shafts in some of the more complex deposits. Some of the pits near Ribaue are very large and have furnished ballast for the railroad and surfacing material for roads. Hand drilling is used both because of cheap labor and the need for careful selective mining in many places.

Milling

All concentration is by hand picking. Commercial minerals are hand sorted in the pits and on the dumps and then often taken to a central point for further processing. Mica is cut and graded at a central shed. Crystals of gem quality tourmaline and beryl are taken to several central plants and there hand cobbed to remove any non-gem portions and later graded as to color and perfection. Since some of the minerals often occur in pockets and rich bands it is not uncommon to sack some of these, as, for example, bismuth ores, in the pit.

Alluvial and Eluvial Deposits

Several of the valleys contain appreciable tonnages of auriferous sands of commercial grade. One company is now erecting a mill to treat several of these deposits.

In addition to the alluvial deposits there are eluvial deposits that have formed over and around some of the larger pegmatites. There is one particularly promising deposit on the slope to the south of and adjacent to the Muiane pegmatite. Here the soil is known to contain gold, columbite-tantalite, bismuth minerals and probably an appreciable number of tourmaline crystals as well as other resistant minerals. It is proposed to run this soil through a mill to recover those minerals that occur in commercial quantities.

Minerals

The minerals known to occur in the district are described in the following paragraphs. No attempt is made to give a comprehensive description of each min-

eral and data are not at hand to warrant such an attempt. An effort is made to describe the importance and quality of the minerals and the size of outstanding crystals and specimens. The larger crystals are now in collections in Mozambique and elsewhere, but since only the surface of the district has been scratched to date future mining will undoubtedly bring to light comparable tonnages of minerals and ores as well as crystals of equal and larger sizes. The descriptions are in the order of economic importance based on past production and sales.

Mica

Mica has been the principal mineral produced from the district. Over a thousand tons have been sold, principally scrap, and there is in excess of a thousand tons remaining on the various dumps. It is classified as "ruby", and cut, spot, and scrap qualities have been produced. There is no production now but should a world shortage develop there is a reserve of several thousand tons of cut and spot mica available in known deposits. In the past the bulk of the production has come from Murrapane and Boa Esperanza.

Most of the cut mica has been of the higher grades but some special sizes have been obtained and non-commercial books more than a foot in diameter are not uncommon. The dumps contain an abundance of scrap with interesting inclusions.

Lepidolite

As regards tonnages produced, lepidolite ranks second. The material found in several pegmatites is of exceptional purity and quality. Unfortunately transportation costs are so high that the material cannot compete on the world market today. A bed of almost pure mineral has been exposed in the Naipa pegmatite with a cross section approximately 35 feet long and 10 feet high with the total dimensions as yet unknown. Over 1000 tons have been stock-piled in connection with mining for other minerals.

The mineral has a fine lavender color and occurs in interlocking books, radiating columns and large tapering crystals. The radiating type produces very attractive specimens with curved surfaces. Some of the tapering crystals at Naipa are 7 by 4 by 2 inches high. Cleavages 14 inches in diameter of less strongly colored material are obtained at Muiane and at Piteia, cleavages 12 inches in diameter.

The radiating material is not unlike that found in Maine and in other areas of complex pegmatites but its purity and deep color makes it unique.

Beryl

Over 100 tons of commercial beryl have been produced together with an appreciable quantity of gem material. In 1949 commercial quality beryl was being produced from at least seven pegmatites and new localities were being opened from time to time. The crystals occur isolated and in pockets in the feldspar along the feldspar-quartz core contacts. Some are three feet in diameter and it is not uncommon to remove whole crystals 18 inches in diameter and 24 inches long. These are usually a mottled green color and the degree of opacity varies from place to place. The potential reserve is unknown but certainly appreciable.

An unknown quantity of gem beryl of light shades has been produced and sold to lapidaries in South Africa. Some of the gem material is found in the core of large crystals and recovered by hand cobbing which results in a considerable loss. Approximately 60% of the gem material is aquamarine, the remainder morganite, golden, colorless, black or dark blue, and several fancy shades. Some is a pleasing cream or pale ecru tint. In general the shades are not deep. A crystal of non-gem quality morganite from Muiane with sharp faces and of a fine deep color 3 inches in diameter and 2 inches high is now in the U. S. National Museum.

The crystals of black or deep blue color are characteristically deeply corroded and often coated with a zone of white alteration. All of the deeply corroded crystals observed tapered to a point.

Columbite-Tantalite

Over one hundred tons of columbite-tantalite have been produced. This mineral occurs in almost every complex peg-

matite and is found in commercial quantities in about ten of the larger ones. It usually occurs in rough to sharp crystals that vary in size from small grains to masses weighing a kilogram or more. Crystals one inch square by two inches long from pegmatites in the southern half of the district often show a number of forms.

The better crystals commonly occur near the contact of the mica and feldspar zones. Although the crystals are good they are inferior to the finest from the Black Hills, South Dakota.

Analyses of shipping lots show less than 20% of the columbite molecule.

Samarskite

There has been a small production of some eight tons of samarskite concentrate from three pegmatites. Fine sharp crystals have been found at Macotaia where it was the only mineral of any commercial importance. It occurs in much the same spatial relationship as tantalite. The crystals are usually less than an inch long but a few larger crystals have been found at Muiane.

Fluorite

Approximately five tons of fluorite have been produced from the Piteia pegmatite. Here it is associated with other fluorine bearing minerals, such as topaz, lepidolite, apatite, etc. It occurred as coarsely crystalline deep green masses along the mica-feldspar contact. It has not been found in vugs to date. Attractive green octahedrons up to four inches were cleaved from some of the material.

It is probable that this mineral occurs in other pegmatites and has been overlooked, particularly in those rich in apatite, lepidolite, etc.

Bismuth and Bismuthinite

Some three tons of bismuth and bismuth minerals have been recovered from two pegmatites and these minerals probably occur in several others. In the Naipa pegmatite a single pocket yielded over half a ton of bismuthinite with some native bismuth. The pocket was mined some years ago and little is known of the relationships of the occurrence. It is not uncommon to find bismuth in complex pegmatites but it is unusual to find such quantities. It will be noted below that bismuth also occurs together with antimony in the unique mineral, stibiobismutotantalite.

Bismuth Carbonates

Pockets containing a hundred pounds or more of hydrous bismuth carbonate have been found at Naipa. It is also found as an alteration product in pockets of bismuth and bismuthinite where oxidation has not been complete. There may be several carbonates intimately associated in the different pockets. One carbonate is greenish and has associated with it white to brownish material. The former is identified as bismutite and the latter may be an alteration. Two analyses of the material are given below. They indicate a mineral with the composition, 3 Bi_2O_3. 2 CO_2. 2 H_2O, but it is probably bismutite with admixed bismuth ocher.

Bi_2O_3	89.46%	88.23%
CO_2	6.29	3.73
H_2O	2.52	3.46
SiO_2	0.61	3.65
Al_2O_3		0.75
Fe_2O_3	0.38	0.04
Total	99.94	99.86

Quartz

The district is noted for its large quartz crystals and the unusual distortion of many of the smaller crystals. Slightly less than two tons of optical quartz have been produced to date.

Massive quartz occurs as a core in the less complex pegmatites and as irregular masses in others. Near Ribaue the quartz is quarried as ballast and road metal.

At Nahia magnificent crystals occur in vugs, some of them more than three feet in length and weighing over a ton. Crystals are rare in other pegmatites. White, distorted crystals are also found at Nahia, and rose quartz at Macula. Some notable specimens have been taken from vugs at Cavala. Here fine sharp crystals up to six inches in diameter occur with coarse tabular crystals of albite. In other vugs

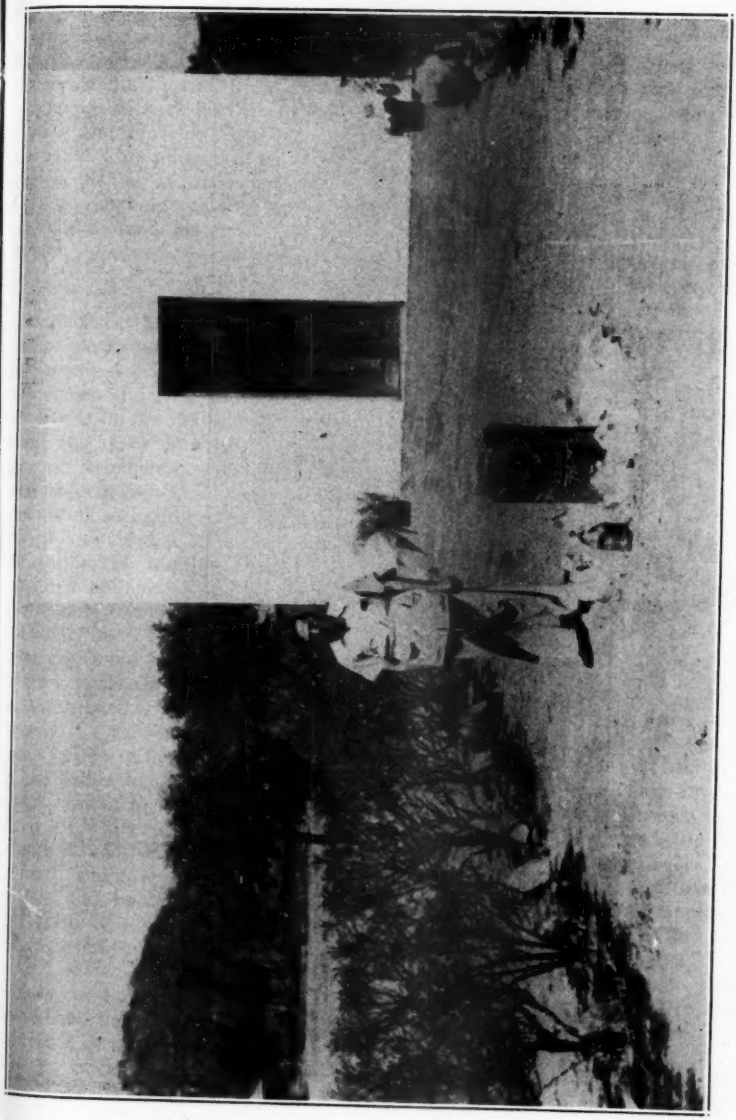


Fig. 2

Mulane. A large beryl crystal surrounded by a number of fine quartz crystals. Note the collection of quartz crystals along the hedge on either side of the walk.

(Photograph by courtesy of the Smithsonian Institution.)

Fig. 3

Tourmaline crystal from the Alto Ligonha pegmatite district, Mozambique, containing a large proportion of gem material of a fine burgandy wine color.—Collection of the U. S. National Museum.

fine crystals of quartz and orthoclase occur together.

Monazite

Over three-quarters of a ton of monazite has come from the district. The writer did not observe it in place but it is reported to have been recovered from Muiane and probably Entata where it is associated with other rare-earth minerals such as allanite, samarskite, etc. A careful field study would probably reveal its occurrence at Piteia, Macotaia and other pegmatites.

Tourmaline

Magnificent tourmalines of finest gem quality have come from the district. The gem material is approximately 60% red, 30% green and 10% brown and yellowish. Much of the red is a fine raspberry shade and many of these crystals have a greenish termination. Total production of gem material has been approximately 250 pounds not including an even larger quantity of crystals that are in museums and collections. In addition the district has produced an unknown quantity of non-gem quality crystals of magnificent colors.

Usually crystals of a single color or duo-color are found in individual pegmatites. Green crystals are found at Naipa, red at Muiane, together with some duo-colored crystals. Crystals up to 3 inches in diameter and 15 inches long have been found at the latter locality. All of the green crystals found to date have been smaller, rarely over one and one-half inches in diameter and five inches long.

Small black crystals occur along the contact and border zone of the simple and mica rich pegmatites embedded in the mica, feldspar and schist wall rock.

Gold

Over two hundred pounds of gold have come from the district. It occurs in small quantities in some of the pegmatites and a nugget of seventy-five grams is reported from a quartz vein or pegmatite at Locuir. The major portion of the production has come from sand and gravel in the valleys below the pegmatites. There is an unknown and probably appreciable reserve of eluvial gold in the vicinity of the Muiane pegmatite. Only recently has an attempt been made to mine the gold in a formal manner.

Feldspar

Massive orthoclase, microcline and albite have been mined with quartz at Boa Esperanda and other pegmatites near Ribaue. There is a reserve of thousands of tons in these deposits near the railroad and in others more distant.

Orthoclase is found in crystalline masses with cleavage faces up to 30 inches across in some of the simple pegmatites. At Piteia fine sharp pink crystals up to 4 inches thick have been found in vugs. Undoubtedly larger crystals have been destroyed in blasts.

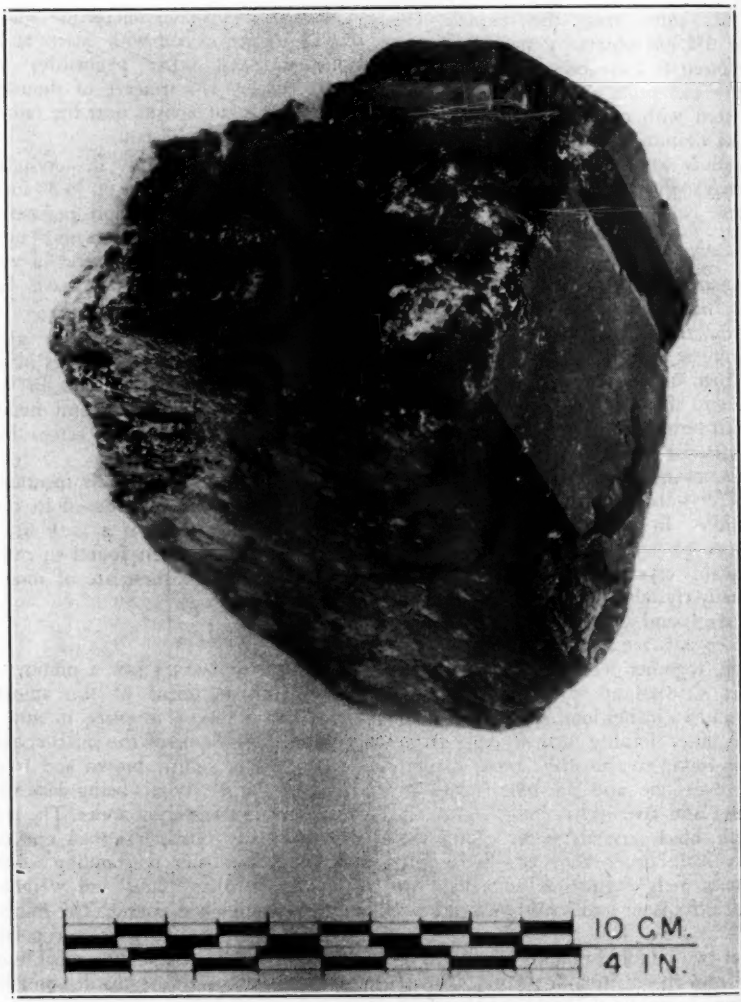
Albite is found rarely in fine glassy platy white crystals up to 6 inches in diameter at Cavala. Here it occurs in vugs with quartz and orthoclase and notable specimens up to 30 inches across have been removed.

In addition to the minerals mentioned above that have been produced in commercial qualities, there is a long list of minerals that have been found in minor quantities. Many of these are of interest because of their size.

Stibiobismutotantalite

Although the writer saw a number of crystals and specimens of this mineral it was not observed in place in any of the pegmatites. Some of the small crystals are colorless or faintly brown and transparent, the larger crystals being dark with transparent to translucent zones. The crystals are usually small, less than one-half inch long, but one outstanding crystal with sharp brilliant faces and weighing over ten pounds was found. The mineral is reported to occur in vugs, particularly in the Muiane pegmatite. It probably occurs in a number of pegmatites and has been confused with tantalite.

An analysis of the mineral, given below shows it to have the composition, Bi_2O_3. 12 Sb_2O_3. 3 Cb_2O_6. 12 Ta_2O_5 or $(Bi, Sb)_2 O_3$ $(Ta, Cb)_2 O_5$. In view of the small percentage of bismuth it would probably be better to identify it as stibiotantalite and regard it as an inter-



(Photograph by courtesy of the Smithsonian Institution.)

Fig. 4

Largest known crystal of stibiotantalite from the Alto Ligonha pegmatite district, Mozambique.—Collection of U. S. National Museum.

mediate member between that mineral and bismutotantalite.

Ta_2O_5	49.66
Cb_2O_5	8.75
Sb_2O_3	35.23
Bi_2O_3	3.98
Al_2O_3	0.74
As_2O_3	Tr.
FeO	0.19
SiO_2 and SnO_2	1.02
Mn	Tr.
Loss	0.35
Total	99.92

Topaz

Topaz crystals up to three feet long are reported from Piteia. These are opaque, rough and of a white to yellowish color. Small crystals, colorless and translucent have been found in the same deposit.

Apatite

Altered crystals of apatite have been found in several pegmatites and probably widely distributed. Nahia is noted for these crystals. White crystals up to 12 inches in diameter and 6 inches high and bluish green crystals up to 6 inches in diameter and 6 inches high have been found.

Garnet

Garnet has been found in several pegmatites, both massive and in crystals. It is commonly red or black and not of gem quality. With a local market it might be mined on a commercial scale at Naipa.

Rare Earth Minerals

Occasionally black minerals with a high luster are found in different pegmatites and these have been identified at one time or another as euxenite, allanite or orthite, gadolinite, and samarskite. It could be that some of these minerals have been identified incorrectly. They occur in quantities so small as to be of interest only as specimens. If such an assembly of minerals does occur a careful study of the district would undoubtedly reveal the presence of other related minerals.

Triplite and other manganese minerals are found in two pegmatites and probably occurs in several others.

Rutile has been found in large, sharp, brilliant, superb crystals at Ribaue. Some of these are reported to have been over two inches in diameter.

Cassiterite has been identified from Piteia but the writer did not see any of the crystals. Since tin oxide is found as an impurity in other minerals it would not be unusual to find it associated with tantalite and bismuth minerals.

Chromite occurs as disseminated grains and small concentrations in serpentine and basic rocks in the southwest section of the district, particularly at Municana or Munucua where an attempt was made to mine it. It is associated with asbestos of inferior quality.

It is noteworthy that such common and expectable pegmatite minerals as spodumene, amblygonite, and others have not been observed or identified. This is probably due to oversight and it would be most unusual if a detailed study of the district did not reveal their presence.

Mineral Association

As an example of mineral association a list is given below of the minerals recognized to date from a single pegmatite, Muiane, one of the larger complex deposits. Some of the common and less noteworthy minerals are not included, as hematite and muscovite. The minerals *underlined* occur in exceptional crystals or specimens.

Muiane minerals:—garnet, *lepidolite*, beryl, *tourmaline*, samarskite, monazite, *stibiobismutotantalite*, bismuth, bismuthinite, kaolin, gold, *albite* and quartz.

Acknowledgment

The writer is indebted to numerous Portuguese government officials in both Portugal and Mozambique who gave him every assistance and accompanied him to the district. The three analyses were furnished by the Mozambique (?) Department of Mines and Geology and the staff was most helpful and hospitable. Special acknowledgment is given to the local operators who extended generous hospitality and gave essential information.

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WHAT'S WRONG WITH OUR MINERAL MUSEUMS?

DAVID M. SEAMAN

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Today as never before in man's history minerals are in the news. Who has not read within the past few years of the strategic minerals needed for defense? Never has the public been so subjected to news about minerals, particularly the pitchblende ores, chief source of vital uranium. Yet the mineral museums are not enjoying an increase in attendance to their exhibits and it is a fact that in recent years a number of our public museums either have closed their mineralogical exhibits or have vastly reduced their number in deference to other exhibits.

Something must be done to enliven the public interest again in our mineral halls. A number of glaring faults immediately suggest themselves as the cause for this condition, chief among which may be listed the following:

1. Inadequate classification and arrangement.
2. Poor lighting of exhibits.
3. Lack of any explanation for what a mineral is.
4. Absence of exhibits explaining how minerals are identified.
5. Poor planning of exhibits.
6. Lack of originality in exhibits.

1. Inadequate classification and arrangement

Perhaps the main fault for our nearly empty mineral halls is that most of them have been arranged from the viewpoint of the scientist, chiefly following the classification of the Dana System of Mineralogy. While this is a very fine arrangement for the mineralogical laboratory, if followed in the exhibit hall the very degree of the completeness and the great number of specimens exhibited are discouraging if not downright overwhelming to a layman. This arrangement is far beyond the understanding of the general public. I have often heard people say, "The minerals are pretty but they don't mean anything to us."

Therefore simplification of exhibits, together with eye appeal, should be the first consideration of the curator if the layman without any training in this field is to become interested. Such exhibits as gem minerals, or birth stones, make attractive exhibits, for most people are interested in gems, particularly the ladies. Nearly everyone knows the gem stone for the month of his or her birth. The gem minerals also have beautiful colors seldom approached by other minerals. An exhibit of this kind may be enhanced by the use of Kodachrome transparencies, or color or black and white enlargements, relating to the mining of gems or the famous gem stones of history. For instance, the interior of a diamond mine may be shown, or the picking tables where the diamonds are caught on grease, or natives mining rubies in Burma. All of these help to make the exhibit more interesting. The excellent Kodachrome photographs of the gems in the United States National Museum which appeared in the December issue of the NATIONAL GEOGRAPHIC MAGAZINE for 1950 may be exhibited with interesting effect along with the actual gem stones. The writer used the colored photographs of the British Crown Jewels which appeared in the NATIONAL GEOGRAPHIC MAGAZINE shortly after the coronation of Edward, Prince of Wales, as a part of a very effective exhibit of amethyst, birth stone for the month of February. A large amethyst was shown in one of the crowns in these photographs. This exhibit was featured in the Carnegie Museum in Pittsburgh, Pennsylvania, in 1949.

2. Poor lighting of exhibits

The exhibits may be well arranged, but if they are not properly lighted, much of their value and eye appeal are immediately

lost. The greater part of anyone's education and much of one's interest are obtained through eyesight. With the beautiful colors of many minerals found in nature, particularly the gem minerals, inadequate lighting spoils the entire effect of a carefully arranged exhibit. I have seen some fine collections of minerals exhibited under abominable conditions. One was in an out of the way place in a city park museum, as though the museum were ashamed of the collection. The public was ashamed of it too. There was a mineral convention in the city at the time and some of the visitors were using flashlights in order to see the specimens. From the viewpoint of lighting, the mineral collection of the Cranbook Institute of Science in Bloomfield Hills, Michigan, is outstanding. The Cranbrook cases are lighted through frosted glass tops and sides by fluorescent lighting. This permits the light to come through while the lighting fixtures are not seen through the frosted glass. The minerals are displayed on plate glass shelves and the lighting brings out all the color and chief features of the minerals which may be appreciated by the eye.

3. *Lack of any explanation for what a mineral is*

This is perhaps the most neglected, if not completely unexplained part of most mineral halls. Many museums do not even attempt to explain what a mineral is. Since this is usually the first question a curator will be asked, it is seen to be uppermost in the mind of the public.

Here at the entrance of a mineral hall is an opportunity to arrange an exhibit both eye-appealing and stimulating and of high educational value. As a suggestion, a Kodachrome transparency of the Bikini Bomb explosion, with a colored wheel revolving behind the transparency to give changing colors to the cloud effect of the explosion, could be used to call attention to atoms. Atoms may be further explained as the building blocks of minerals. The explosion itself then may be shown to be due to the disruption by artificial means of the natural attractive forces of the particles within the atom itself. The atom, or building block, then may be likened, using the hydrogen atom as an example, to our earth, as if the earth were an electron revolving around the central nucleus of the sun, itself the proton or positive charge at the center of the atom. It might be possible to arrange a push-button mechanism to start in motion a small steel ball attached by an invisible, steel wire to a larger steel ball for the center of the atom and to have it swing around in a circle to show the motion of an electron around a proton. Below this exhibit could be displayed a few purified elements, as sodium and chlorine, with a diagram beside them showing the charge on the nucleus of each atom and the number of electrons surrounding the nucleus. A neighboring exhibit could illustrate the orderly arrangement of the sodium and chlorine atoms in the mineral halite by the use of a crystal model showing how they combine in nature to form this simple mineral. A natural crystal of halite, a nearly perfect cube resembling a child's building block, might be exhibited beside the crystal model to call attention to the six cubic faces of the crystal as the external effect of this orderly arranged internal atomic structure. The faces which appear as the bounding surfaces of the natural crystals then can be related to various planes of atoms taken in a number of directions throughout the crystal model.

4. *Absence of exhibits explaining how minerals are identified*

A very interesting exhibit showing many of the physical and chemical properties of minerals may be set up calling attention to such important means of identification as cleavage, fracture, hardness, streak, specific gravity, certain characteristic chemical tests for various elements as the borax bead tests for manganese and cobalt and the wet tests for copper, aluminum and iron. A difference in the index of refraction, or the degree of bending of light as it passes through a mineral, really may be illustrated by displaying together two cut gems of synthetic rutile and colorless topaz, the striking difference in brilliance between them

being largely dependent upon difference in their refractive indices. One can show how minerals are fingerprinted by comparing two minerals displayed side by side with their corresponding x-ray powder photographs. Each mineral is then seen to have its own individual fingerprint, and the x-ray photogaphs are used like human fingerprints for exact identifications.

5. Poor planning of exhibits

A number of museums seem to have their mineral exhibits arranged without regard to any purposeful order or without any attempt to call attention to minerals of particular or local interest to the public.

Every museum should have an exhibit of fluorescent minerals for this is the exhibit attracting most attention in any mineral hall. I have particularly noted that small children are entranced by it. Many of them bring their mothers and fathers into the mineral hall to see this one exhibit. After viewing the display, the parents as well as the children are stimulated toward wanting to see more of nature's handiwork and thus the other minerals on exhibit.

For a museum located in the heart of steel making, such as the Carnegie Museum in Pittsburgh, Pennsylvania, the exhibit which the writer had there of the minerals used in the making of steel and its alloys, proved very interesting to Pittsburghers. Exhibits related to industries of any particular city or region always have great local interest as well as attracting much attention from visitors. The same type of exhibit showing the chief minerals used in the making of automobiles has proved very effective at the Cranbrook Institute of Science located near Detroit, Michigan.

The minerals found in a particular State in which a museum is located, or from a nearby locality, can attract much interest. The zeolite minerals from the quarries around Paterson, New Jersey, as stressed by the Paterson Museum, are an example As new specimens from these quarries are available to local collectors, gifts of these to the museum can add constantly to the quality and interest of the material exhibited.

The museums of various mining cities can stress the economic minerals of their region or State to great advantage, as does the museum of the Colorado State Bureau of Mines in Denver, Colorado. This large exhibit of some eleven thousand specimens has been arranged in such a way as to call special attention to the minerals which are found in every County of the State of Colorado. This exhibit is of particular interest to many Coloradoans who are naturally mineral-minded, living in a State so abundantly blessed with minerals, and many of whom derive their income from mineral industries.

For a museum such as the Mineral Museum of Harvard University in Cambridge, Massachusetts, the display of New England minerals featuring the fine minerals from New England pegmatites has a special local interest. Most of these localities can be reached in a day's drive from Harvard. The pegmatites, as the source of various gem minerals found in this area, are much visited by the members of the Boston Mineral Club.

Several large exceptionally beautiful specimens, well displayed and all alone in seperate display cases, can attract more attention and interested comment than thousands of specimens meticulously arranged. As an example, the quartz group from Dauphine, France, with over twelve hundred individual crystals, has been attracting very great attention from the public in the Harvard Mineralogical Museum.

An active Mineral Club located wherever a Mineral Museum exists does much to stimulate the amateur collectors of the area and create local interest. An appropriate meeting place for this group can be in the museum itself. Cooperation between Club members and Museum staff always is of great mutual benefit.

6. Lack of originality in displays

Changing monthly exhibits in a museum can do much to create new interest, especially for those who come repeatedly to see the mineral displays. Here is an opportunity for a curator to express real

originality in the exhibits. For instance, an interesting exhibit for the month of June may be easily arranged. This month immediately brings to mind weddings and wedding anniversaries. With these as a theme a display of the chief metals and gems appropriate for the various wedding anniversaries may be used with great effectiveness.

Another exhibit of this type could be a fluorescent Christmas Tree for the last two weeks in December. Both fluorescent and non-fluorescent minerals could be arranged on the tree in such a way that it would be beautiful both under artificial light and under ultra-violet light. Crystals of a number of the more colorful minerals, as those of azurite, malachite, wulfenite, sulphur, quartz, etc., in sizes not over an inch or an inch and a half in size may be used to great advantage under ordinary electric light. Under ultra-violet light, only the fluorescent colors of the minerals are important.

For the month of October with Hallowe'en and its masks and masquerading, an exhibit of mineral pseudomorphs should make an interesting display. These deceptive crystals have false faces, possessing the outward crystal form of one mineral and the chemical composition of another, and may be explained in terms of Mother Nature's own masquerading. A few typical Hallowe'en masks appropriately arranged can serve to call attention to this exhibit. A Kodachrome transparency or color print of the Arizona petrified forest may prove interesting along with this exhibit to illustrate the extent of nature's masquerading. Here entire forests have been turned into stone, or rather into minerals, with replacement of the wood by such minerals as opal, chalcedony, and jasper.

Exhibits of current interest, such as minerals used in the atomic bomb, are of interest to nearly everyone. Photographs of the bomb explosion which appeared in color sometime ago in the NATIONAL GEOGRAPHIC MAGAZINE add much to an exhibit of this kind. Such an exhibit attracted a lot of attention at the Carnegie Museum three years ago. Another display having current interest might show the principal tin minerals and the uses of tin, chiefly the making of tin cans. Such an exhibit could be set up at the time of the local canning season.

Not enough originality has been shown in planning the exhibits in our Mineral Museums. Too many of them have followed the same old pattern, the scientific approach and nothing more. Scientific accuracy must be maintained; but efforts to explain a lot of complicated mineralogy to the layman simply turns him away from the exhibits.

What then would serve as a general plan for a mineral hall if the scientific approach were minimized? A much more logical approach would be from the geological point of view, stressing the occurrence of minerals as they are actually found in the ground. In this manner those minerals would be placed together which are found associated in the same kind of mineral deposit or rock. As an example, lead and zinc minerals occur so commonly together in the same mineral deposit that they could be shown to advantage in a single display. Other similar displays might be of the precious metals, gold, silver and platinum minerals, or the saline minerals, as halite, gypsum and the borates. From the viewpoint of rock association, a number of mineral groups quickly suggest themselves in the igneous, sedimentary and metamorphic rock-forming minerals. Minerals occurring in lavas, as the zeolites, or agate and chalcedony, would be another group. A further grouping could be from the viewpoint of the industrial uses of minerals: as those minerals used in making steel and its alloys; minerals used for abrasives, as quartz, garnet, sapphire and diamond; fire-resistant minerals, featuring chrysotile and other asbestos minerals; and minerals of medicinal use. A proper balance should be maintained between minerals illustrating geological environment and those representing industrial applications, and would greatly add to the enjoyment and interest of the public in any Mineral Museum.

A NEW ZEOLITE LOCALITY ON DISKO ISLAND, GREENLAND

ARTHUR J. BOUCOT

Amateur mineral collector of Philadelphia; now completing graduate work in geology (special field: paleontology) at Harvard University.

During the summer of 1947, Mr. Boucot was a member of the MacMillan expedition to Greenland. The collecting excursion he describes took place at that time.

In the late afternoon, after sailing all day across fog-covered Disko Bay, we broke out into the sunlight and discovered Godhavn dead ahead. This tiny village, which rests on a massive foundation of Pre-Cambrian granites and gneissic rocks, is the capital of North Greenland. Behind the village, beetling crags rise to heights of several thousand feet. These crags, of Cretaceous age, are layered basaltic lava flows which show columnar jointing, have reddish oxidized tops, and range in thickness from 40 to 100 feet. Erosion is rapidly destroying these massive ramparts; each cliff is skirted by a steep talus cone, which funnels debris to the rock stream below. To the mineral collector, the granitic rocks around Godhavn are disappointingly barren. The basaltic flows and the talus cones, on the other hand, are rich in zeolites. In addition, several occurrences of native iron in the vicinity have been recorded for more than a hundred years.

Collecting in this part of the world is complicated by the Eskimo audience that inevitably follows any visitor. At first they were puzzled and amused (Eskimos are amused easily) by the spectacle of a grown man hammering stones and bending down to peer closely at the ground. Moreover, this amusing collector got out his magnifying glass, screwed up his face, and gave what appeared to be serious attention to these stones.

The collector having quickly exhausted his bag of tricks, the novelty wore thin and most of the Eskimos drifted back to their huts. Two boys in their teens, who seemed to understand what we were up to, stayed with us and began to bring rocks for our inspection.

At the base of the rock streams, we looked for amygdules that might contain zeolites. Some of the cavities, which measured under a few inches in diameter, contained abundant white chabazite; others were lined with stilbite, apophyllite, or heulandite. The Eskimo boys were keen-eyed and found abundant material, once they understood what was dross and what was desired.

Zeolites are remarkable for their uniform manner of occurrence the world over. The Godhavn locality is no exception; here one finds relatively flat-lying basalt flows, the tops of which are pockmarked with zeolite-filled amygdules, vugs, and geodes. These cavities probably represent vapor-filled bubbles that never reached the flow surface because of rapid chilling of the basaltic lava. The zeolites may represent the precipitated residue of the original vapor, rich in water, alkalies, silica, and alumina.

At length, we cached our specimens at the base of the talus cones and started climbing up over the steep piles of loose rock, which seemed to have an angle of repose of about 45 degrees. We worked our way to the top of the cone, a vertical height of perhaps a thousand feet, before we gained foothold on a sharp ridge of heavily-jointed basalt. While we stopped to catch our breath, we rolled a large boulder down over the side of the ridge and then watched the cascade of living, bouncing boulders it started in its wake, leaving the whole talus cone literally roaring and bouncing as one boulder set others in motion.

Finally we reached the top of the peak, called Lynmarkij by the natives. The top was entirely bare of vegetation, except

for a few hardy saxifrages that somehow had found a foothold in rock crannies. The whole climb had been more rigorous and dangerous than we had anticipated, but we did not want to be the first to turn back and we suspected that our Eskimo companions entertained the same unwillingness. It was now 1:00 a.m. From our peak, we could see the whole harbor spread out below in miniature. Our ship rested quietly, motionless on the still sea. The air was calm, the sun very low in the sky.

The climb down, though no less arduous than the ascent, was much faster. On the way, we accumulated a large quantity of white chabazite from the oxidized flow tops, and with our heavy loads we glissaded down the piles of smaller debris. At the base of the cone we picked up the material we had collected earlier and struck out for the ship across a flat area covered with a gravel of weathered basalt. This gravel was segregated into the stone stripes, nets, and circles so characteristic of the far north. Here and there plants that dammed the "flow" of the gravel. had obtained a foothold, forming terraces Certain areas were covered with a growth of bluebells, which swayed gracefully before the impact of each passing breeze.

Our Eskimo friends rowed us back to the ship, where we treated them to lukewarm tea, ship biscuit, and peanut butter. After the exchange of autographs and the smoking of cigars, the Eskimos left the ship and our evening's collecting trip was over.

CRYSTAL COLLECTING AT SARATOGA SPRINGS, N. Y.

ELMER B. ROWLEY

Business Man (Insurance) in Glens Falls, New York; amateur mineral collector.

For a number of years the Gailor Stone Quarry on North Maple Avenue in Saratoga Springs, New York, has been a source of outstanding crystallized specimens of quartz, calcite, and dolomite. The quarry has been operated intermittently over many years for the production of crushed stone for use as road metal. Within the past several years the quarry has not been operated, since the transmitted shocks of the blasting operations were causing damage to homes in the vicinity. The quarry is located on the west side of Route 9 on the northern edge of Saratoga Springs, New York. The open pit is in plain view from the highway, just north of the first traffic light as one enters Saratoga Springs from the north.

General Geology

The geology of this region is complicated by reason of the fact that many of the rocks are largely buried beneath a mantle of Pleistocene sands which precludes any easy interpretation of their structure and sequence. Several major faults have also caused displacement of the formations throughout the area. The detailed geology of this area may be found in New York State Museum Bulletin No. 169, Geology of Saratoga Springs and Vicinity, by H. P.Cushing and R. Ruedemann, 1914.

Saratoga Springs is situated near the southeastern edge of the Adirondack Geological Province of pre-Cambrian age. That Province formed a part of the Primitive North American Continent and existed as ancient mountain ranges; during Paleozoic time erosion of these supplied debris to great seas lying to the south and southwest.

The three major sedimentary deposits laid down in this area during Cambrian time are the Potsdam, Theresa and Little Falls formations. The Potsdam, a sandstone, grades downward from fine-grained clastic materials to coarse conglomerates suggesting vigorous erosive activity on bordering highlands over long periods of time. Toward the latter part of deposition of the Potsdam the highlands were evidently reduced to a surface of relatively low physical relief.

Overlying the Potsdam beds is the Theresa Formation characterized by alternating layers of fine-grained sandstone and dolomitic limestone in its lower portion, and alternating layers of pure limestone and dolomitic limestone in its upper portion.

The last sediments to be deposited in Cambrian history comprise the Little Falls Dolomite Formation, a name given to those rocks at the type locality at Little Falls, New York. This formation is essentially massive dolomite with an intermixture of detrital quartz at various horizons suggesting deposition in shallow waters near sand beaches. Its color range is from light gray to dark gray. The formation exhibits no well-defined bedding planes.

Little Falls Dolomite at the Gailor Quarry

The Gailor Quarry rock represents an eastern segment of the Little Falls Dolomite occurring farther west in New York in the region around Little Falls, Middleville, Diamond Hill and Salisbury. This isolated segment lies between two major faults, the Saratoga Fault on the east and the Woodlawn Park Fault on the west. The segment represents a normal fault block with the upthrow side along its eastern edge and the downthrow side along its western edge.

The rock within the quarry is typical massive dolomite with much included chert in the form of nodular masses and stringers. The presence of abundant chert suggests that the silica originally deposited in the lime muds by various marine organisms was later redeposited as crystalline chert. The dark color of the chert is probably the result of included carbonaceous material.

Crystal cavities

The Little Falls Dolomite is the host rock within which are found most interesting vugs containing large and perfect crystals of quartz, calcite and dolomite. Many of these cavities represent joints which are the result of contraction caused by shrinkage of the limestone during dolomitization. Some of these openings have been enlarged by subsequent solution processes of circulating ground waters before deposition of later mineral-bearing solutions. Possibly the processes of solution and mineral deposition were contemporaneous, at least in part.

Cavities may be found throughout the entire formation, but along certain horizons they are more abundant than in others. Within the Gailor Quarry most of the crystal cavities are now found just beneath the central floor of the older quarry in a recent excavation where the center of the original pit was deepened. However, some very fine crystal-lined vugs have been opened up also along the base of the southern wall of the older excavation. The size of the cavity openings ranges from very narrow ones parallel to the contraction joints up to vugs a foot or more in diameter; occasionally larger

Fig. 1

Map showing location of areas of Little Falls Dolomite (in black) where Herkimer "Diamonds" are found.

pockets are found.

There are no definite external characteristics indicating the presence of a crystal cavity. However, some of the contraction joints have been filled by secondary quartz or calcite, and evidence of coarser crystallization along those veins may indicate proximity to a wider opening in the vein, possibly a crystal cavity.

Later Mineralization

Circulating ground waters rich in silica have deposited the beautiful quartz crystals found within these cavities. Where the solutions were rich in lime or magnesia they deposited abundant crystals of calcite or dolomite. More rarely solutions carrying copper, iron, sulphur, zinc or lead have deposited occasional sphenoids of chalcopyrite, or microscopic cubes of pyrite, or sphalerite in small masses and minute crystals. In some cavities much cerussite is found as a secondary coating on crystals of dolomite, quartz and calcite. Within some of the cavities are found considerable quantities of a black carbonaceous material in soft, pulverulent masses. This is apparently some derivative of the hydrocarbon family.

Herkimer Diamonds

Quartz crystals from the Little Falls Dolomite have long been known to mineralogists, and owing to their brilliance and beauty of form have been termed "diamonds." Various localities have produced these crystals. The Little Falls Diamonds, Herkimer Diamonds, and Lake George Diamonds, the latter from Diamond Point and Diamond Island on Lake George, are the best known, although fine crystals of similar character are found in other areas.

The best of the quartz crystals found at the Gailor Quarry are comparable to the finest Little Falls Diamonds found at the type locality near Little Falls 70 miles to the west. The two localities differ somewhat in mineral occurrence and association. Most of the quartz crystals from Little Falls do not share their crystal cavities with any other minerals. At Saratoga Springs, the quartz crystals are always found in association with dolomite or calcite, or with both. Some of the quartz crystals from the latter locality are intergrown with partially enclosed single dolomite crystals suggesting contemporaneous crystallization. Most of the quartz crystals from Little Falls when found attached to the cavity walls are fastened to their terminal rhombohedron points, while those from the Gailor pit are usually attached along prism faces. Many Little Falls Diamonds are found loose in their cavities whereas at the Saratoga Springs locality unattached crystals are rarely found at the bottom of the cavities.

An unusual crystal pocket

One large cavity opened by the writer contained large fragmentary masses of rock crystal, with no associated calcite and only minor dolomite. The horizontal opening measured nearly 3 feet long by 15 inches wide and had an average depth of 6 inches. Those broken fragments included several sections of crystal prisms ranging in size from small pieces 1 and 2 inches in cross-section, up to one piece that was 10 inches long and 3 inches wide. Practically all of the larger masses were unattached to the cavity walls, although one piece was found fastened to a detached "float" segment of dolomite, which in turn was covered with small dolomite crystals.

Later examination showed that the entire mass of quartz had been broken and then recrystallized. While many of the quartz segments showed evidence of being broken by blasting, having jagged edges, subconchoidal fractures, and being much shattered, by far the larger majority of these pieces had perfectly smooth planes along broken surfaces with the edges between those planes rounded over as if fused. Two pieces which had appeared to be broken segments 2½ inches long were found to be distorted doubly-terminated crystals of clear rock crystal.

The most interesting specimen from this pocket was the crystal attached to the "float" segment of dolomite. When this specimen was cleaned up it appeared to be a nice but quite ordinary quartz crystal on matrix. The matrix measured 1 x 4 x 6 inches and the crystal attached to

the dolomitic limestone along a prism face, measured 3 x 2 x 3 inches. Three terminal rhombohedral faces seemed to be complete and perfect, the others only partially complete or missing. Portions of three prism faces were present, with the other three missing. Closer examination revealed that both the transverse fracture across the 3 inch diameter of the prism and the fractured exposure at the terminal end of the crystal were not recent breaks, but older breaks that had been repaired through recrystallization along the broken zones. A careful search through the remaining material within the cavity uncovered the missing terminal segment showing the three incomplete rhombohedral faces to be all there, and a portion of the three missing prism faces. The matching segment measured 7/8 x 2 x 2¾ inches. This terminal section was broken along a plane roughly parallel to one of the rhombohedral faces, and its broken surface had been completely recrystallized. The external facial planes of the crystal section attached to the dolomitic limestone have many microscopic doubly-terminated quartz crystals partially embedded in them while the corresponding facial planes of its matching terminal section have none. This represents one of the most interesting specimens from a crystallographic viewpoint the writer has ever seen. The two disjointed fragments fit together very nicely to form a perfectly complete and symmetrical crystal.

Several other large crystal sections and terminations of fine quality were obtained from this pocket. Some of them exhibit well-defined vicinal prominences of considerable size on the rhombohedral faces. All of the quartz from this pocket showed much evidence of attack by secondary circulating solutions.

Some years ago the writer saw a cavernous doubly-terminated quartz crystal around 6-8 inches long and of outstanding quality which had been picked up by one of the workers in the quarry. It was a very pale smoky color.

Calcite crystals

Calcite is of quite common occurrence at this pit, and some especially choice crystals have been found here, although most of them are quite small. The crystal habit is predominantly basal-rhombohedral, although a few tiny dog-tooth scalenohedrons have been observed. Two or three large crystallized masses of calcite show a crude scalenohedral development. Only one prismatic calcite crystal has been seen by the writer and that one had short stubby prism faces, terminated by rhombohedral facial planes.

Other associated minerals

In some cavities the calcite is associated with brilliant microscopic cubes of pyrite. Occasionally the pyrite crystals are arranged in a zonal pattern along the edges of the rhombohedral faces of the calcite crystals. In other cavities the pyrite has been completely oxidized leaving tiny iron-stained solution pits on the surface of the calcite crystals.

On a cleavage face of white calcite the writer found two perfectly defined hexagonal films of brassy-yellow color. It is very likely that these are either pyrrhotite or pyrite, the latter perhaps as octahedrons greatly flattened on an octahedral face.

One other specimen contained a black platy mineral embedded in white calcite which proved to be an anthracitic hydrocarbon. An x-ray powder photograph, through the courtesy of Dr. Clifford Frondel and the Berman Laboratory at Harvard University, gave a very diffuse pattern which was identical with that of graphite. Its infusibility and very low specific gravity are in accordance with this identification. No other similar specimens have ever been seen by the writer from this locality.

Sphalerite is not uncommon as very tiny cleavages embedded within the dolomitic limestone near cavities containing considerable calcite. Only one perfect and complete crystal 3/8 x 3/8 inches in size has been observed by the writer from the Gailor pit.

Cerussite occurs in relative abundance as secondary coatings of granular white material completely covering all types of crystals lining the cavity walls. It is, therefore, the final mineral to have been de-

posited here (and in all probability the deposition is a continuing process, as cerussite may be deposited at shallow depths.) The occurrence of cerussite is spotty, with some cavities barren of this mineral and others plentifully supplied. No crystals have been noted. This occurrence represents a new locality for this mineral in New York State.

Aragonite is found in minor quantities as a secondary coating on calcite, and as a cementing agent. Under ultra-violet, long-wave radiation it fluoresces pale bluish-white.

Wedged into the bottom of each cavity one can find a most interesting series of choice crystallized specimens. In most instances dolomite "float" segments (which correspond in their relative size to the size of their matrix cavity) have fallen to the bottom of these cavities. In that position they have been subjected to apparent processes of contemporaneous dissolution and crystallization. The process of dissolution has permitted those loose segments to conform to the physical contour of the cavity bottom, and subsequent crystallization has produced crystal forms on them which fit together and interlock in much the same manner as the pieces of a jig-saw puzzle. Owing to the character of those interlocking segments great care should be exercised in their removal as quite obviously the attached crystals may be easily bruised or broken. The crystals in any one cavity seem to be either predominantly quartz, or calcite, seldom in equal proportions.

Some of the specimens obtained from these cavities are especially interesting. In some of them flat platy calcite and individual quartz crystals have been cemented together by subsequent deposition of secondary aragonite, to form most unusual groupings. In those few instances where loose quartz crystals are found they usually occur as complex crystal forms, often showing a parallel growth development. They also include choice but tiny scepter crystals, pale smoky quartz and doubly-terminated crystals attached to crystal-clear rock crystal, and other types of combinations. Twinned quartz crystals of the Brazil type are found here.

From the viewpoint of the crystal collector the Gailor Quarry is a locality of great interest. At the present time the rocks in the pit have been picked over quite thoroughly with the obvious result that fine quality specimens are difficult to find. This does not mean that good material can no longer be obtained, but most certainly not as easily as in the past. The serious collector at the Gailor pit can always get fine crystals by an expenditure of the necessary effort and time.